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Cost Benchmarking for Nuclear Power Plant Decommissioning

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Foreword

Decommissioning experience in relation to nuclear power plants (NPPs) and other nuclear fuel cycle facilities has been gathering steadily in past years. Concerns remain, however, about the ability to accurately calculate and demonstrate the validity of decommissioning cost estimates, as well as to control the costs during decommissioning.

The Nuclear Energy Agency (NEA) has long been working towards gaining greater insight into the costs of decommissioning nuclear facilities, releasing a number of guidance documents on important aspects of cost estimation for nuclear decommissioning projects, including:

- *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (the "ISDC"), a harmonised international approach to the presentation of decommissioning cost estimates published jointly with the European Commission (EC) and the International Atomic Energy Agency (IAEA) (NEA, 2012);
- *Guide for International Peer Reviews of Decommissioning Cost Studies for Nuclear Facilities* (NEA, 2014);
- *The Practice of Cost Estimation for Decommissioning of Nuclear Facilities* (NEA, 2015);
- *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities* – published jointly with the IAEA (NEA, 2017).

Taken together, these publications establish a good basis to produce comprehensive cost estimates for nuclear decommissioning projects and to enhance confidence in the estimates, while providing improved transparency of the underpinning data and calculations, and a more explicit representation of the uncertainties and risks that may affect project costs.

Another, recent report by the NEA, entitled *Costs of Decommissioning Nuclear Power Plants* (NEA, 2016a), presents the results of an NEA review of the overall funding practices adopted across NEA member countries in relation to the costs of decommissioning NPPs.

In recent years, the focus has increasingly been on the need to better understand the variations between cost estimates, the relationship between estimated and actual costs, and concerns about the apparent escalation of decommissioning costs (Invernizzi et al., 2017). In 2016, the NEA Steering Committee "acknowledged the need to expand and improve cost benchmarking data as well as the understanding and acceptance of benchmarking as a valuable tool for all parties concerned" (NEA, 2016b). The present report, *Cost Benchmarking for Nuclear Power Plant Decommissioning,* aims to address these issues and build on earlier guidance and analyses by the NEA, examining approaches and methods relevant to the benchmarking of costs in relation to the decommissioning of nuclear power plants.

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List of abbreviations and acronyms

DCEG	Decommissioning Cost Estimation Group (NEA)
D&D	Decommissioning and dismantling
FMI	First Marine International (United Kingdom)
IAEA	International Atomic Energy Agency
ICMS	International Construction Measurement Standards
ISDC	International Structure for Decommissioning Costing
KPI	Key performance indicators
NDA	Nuclear Decommissioning Authority (United Kingdom)
NEA	Nuclear Energy Agency
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
OMS	Operation, maintenance and security
RICS	Royal Institution of Chartered Surveyors (United Kingdom)
WPDD	Working Party on Decommissioning and Dismantling (NEA)

Chapter 1. Introduction

The number of nuclear power plants entering the decommissioning phase will increase significantly in the coming years, with a corresponding need to:

- demonstrate that decommissioning cost estimates are a reliable basis for understanding actual costs;
- facilitate the collection of relevant information and cost data from NPP decommissioning projects;
- make use of the above information and data on costs to improve management tools that support effective and efficient delivery of decommissioning projects.

While the development of decommissioning cost estimation methods is ongoing, and experience is expanding in their application, the relationship between estimates and actual decommissioning costs has yet to be systematically examined. Addressing the relationship between estimates and actual costs requires the collection and analysis of data relating to cost estimates, as well as information on the actual costs incurred. It also requires information on the relevant, specific contexts or conditions in the individual countries, as well as any additional information on factors that may have an impact on costs. For the purposes of this report, such an analysis is referred to as "cost benchmarking".

Developing and applying cost benchmarking approaches appropriate for decommissioning projects would facilitate the systematic analysis of actual decommissioning project cost outcomes, including in relation to the original cost estimates. It would also yield valuable insights about key cost drivers in actual decommissioning projects, and the extent to which current cost estimates accurately capture and reflect these cost drivers. Aligning the reporting of decommissioning project costs with the underpinning cost estimates would thus facilitate the identification of causes of major deviations between projected and actual costs.

A major challenge arises for cost benchmarking in the context of NPP decommissioning, because relevant project and cost data is not always made readily available. Understanding the specific nature of the difficulties and barriers to sharing and analysing nuclear decommissioning project information relevant to costs, from the perspective of different stakeholders, is therefore key to understanding if and to what extent these factors may be addressed. It is therefore fundamental to determine the potential added value of developing and implementing cost benchmarking in the context of nuclear decommissioning.

1.1. Objectives

This report provides policy makers, regulators, strategy and decision makers with a description and an analysis of the practice and methodology of cost benchmarking in the context of NPP decommissioning. It also suggests new approaches to cost data sharing and analysis, and promotes the development of benchmarking methodologies specific to NPP decommissioning.

1.2. Scope

The report draws on the experience of NEA member countries in developing and implementing approaches for cost benchmarking suitable for nuclear decommissioning projects, including experiences in decommissioning other types of nuclear infrastructure (i.e. nuclear facilities other than NPPs). The report takes into account related developments in other industry sectors, such as oil and gas, some of which are better served by more mature cost benchmarking approaches than those in the nuclear sector.

Particular focus is given to identifying key factors, drivers and constraints to implementing cost benchmarking in the context of nuclear decommissioning. These are addressed from a broad range of perspectives in order to help identify a path forward that might enjoy sufficiently broad support from a wide base of interested stakeholders.

While the specific focus of this report is on the application of cost benchmarking in the context of NPP decommissioning, the methods and approaches considered herein are nonetheless intended to be generally applicable and therefore relevant – with suitable adaptions – to the decommissioning of all nuclear facilities.

1.3. Organisation of the report

The findings presented in this report are based on the experiences in, and insights from, NEA member countries as provided and collected by experts in the benchmarking activity within the NEA Decommissioning Cost Estimation Group (DCEG).

The added value that could potentially be realised through implementing cost benchmarking for decommissioning from a variety of stakeholder perspectives is discussed in Chapter 2 of this report. Chapter 3 of the report presents approaches to cost benchmarking in a range of other industries, and Chapter 4 provides information on approaches to data collection and sharing, including for highly sensitive data, and how these might inform the identification of appropriate methods for collecting and sharing the information required for benchmarking for decommissioning. This chapter also includes an important discussion on the barriers to such data sharing, and the potential for enabling the removal of such barriers. Chapter 5 of this report then summarises the findings and conclusions, and provides overall recommendations.

The appendices include further information on the individual aspects described in this report, as well as case studies reflecting experiences in NEA member countries. More specifically:

- Appendix A: Case study from Sweden – Interface with project delivery tools;
- Appendix B.1: Details of barriers and enablers identified by nuclear industry stakeholders;
- Appendix B.2: Approach to ascertaining stakeholder interest in NPP benchmarking;
- Appendix B.3: Additional analysis of cost benchmarking options.

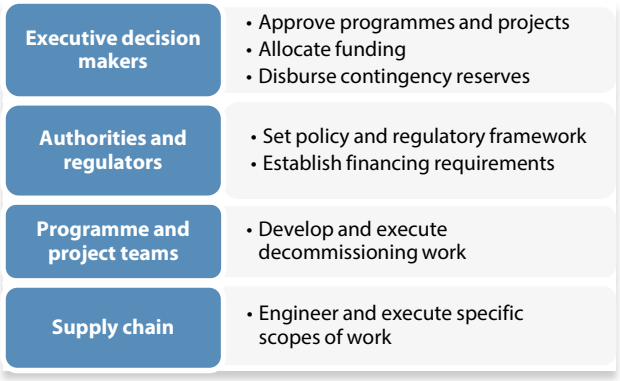
Chapter 2. **Added value**

Cost benchmarking adds value to different stakeholders in a variety of ways, and the utility of cost benchmarking varies as projects mature through their lifecycles. This chapter explores the perspectives of different stakeholder groups, and ways in which their needs change through time.

2.1. **Stakeholder perspectives**

Though countries vary in the organisation of their nuclear industries, all share common characteristics in terms of having groups of stakeholders who have differing needs for cost and schedule estimates, and thus differing interests in the cost benchmarking process. These typical stakeholder groups include: executive decision makers; authorities and regulators; programme and project teams; and the supply chain. The needs of stakeholders in the nuclear sector are likely to be similar to those already demonstrated in other industries. Accordingly, a general description of these needs may prove to be useful as a basis for the approach of this report.

Figure 2.1: **Key groups of stakeholders and their roles**



Executive decision makers

The stakeholder group of executive decision makers commissions the work, decides on strategy, approves funding, manages the disbursement of risk contingency reserves, and as such has a keen interest in receiving accurate cost estimates. Typically, executive decision makers include owner/operator roles such as Chief Executive Officer, Chief Financial Officer, other executives in charge of project shaping and delivery, and the boards of operating companies. Executive decision makers are interested in the ultimate decommissioning costs as early as possible during the new-build process, in order to incorporate these into cost-benefit considerations of the economic viability of projects. Such decommissioning cost estimates might also form the basis for the financing of future decommissioning activities. In both cases, underestimating or overestimating, such costs may contribute to distortions in decision making.

More obviously, executive decision makers must approve decommissioning work at different points in time, typically through decisions taken in stage-gated processes when decommissioning programmes and projects mature. Such approvals require accurate estimates of both the magnitude of funding required and the phasing over time (and hence of the schedule).

Executive decision makers are reliant on programme and project teams to provide them with business cases incorporating not just point estimates of costs and schedules, but also ranges of probable outcomes. Quality decision making relies on the provision of reliable estimates at an early stage of the project initiation process. This helps establish the strategy and consideration of alternative approaches. During the early stages of projects, cost estimation largely relies on analogous comparisons because of an inherent low engineering definition, i.e. benchmarking with initiatives of similar scope. Benchmarking is thus a necessary tool in the earliest stages of the project lifecycle.

Using cost benchmarking as a tool helps to make the actual outcomes of scope, cost and schedule available to others in the form of a lesson learnt. The value that cost benchmarking adds to executive decision makers is in bringing better quality of information about possible outcomes within realistic ranges. Executive decision makers are generally unable to comment in detail on bottom-up cost and schedule estimates, based on thousands of elements and assumptions, but they are capable of probing why project teams might present an arbitrary or too-narrow range of cost estimate values that might not overlap with actual outcomes of analogous projects elsewhere. In this sense, cost benchmarking at the project/programme level allows executive decision makers to challenge project teams to remove optimism bias, and to actively compare and contrast their initiatives with analogues.

Authorities and regulators

Bodies that oversee the executive decision makers commissioning projects include regulatory bodies and governmental authorities. Authorities and regulators have responsibilities to ensure that financing for decommissioning is adequate. They may also have additional oversight responsibilities such as ensuring value for money in project delivery. Authorities and regulators thus have an interest in assessing the competence of the executive decision makers' ability to provide accurately estimated programmes of work. Authorities and regulators in other industries often require that cost benchmarking be undertaken as part of the process of oversight. Authorities and regulators sometimes create their own cost benchmarking datasets in order to compare and contrast operator proposals.

Cost benchmarking provides authorities and regulators with insight into whether operators (and the decision makers among them) are providing value for money to taxpayers/customers; whether they are efficient stewards of capital; whether they have competent processes for shaping and executing programmes of work; whether their policies are working; and whether operators have selected appropriate strategies to implement their policies.

Authorities and regulators may also use cost benchmarking to identify the magnitude of systemic sector premiums, and the root causes of such premiums. Ideally, this should also contribute to the identification of measures to make the entire industry more efficient. In this sense, authorities and regulators are not only interested in benchmarking capital/abandonment expenditure, but also in operating expenditure.

There is a perception by some national regulators that cost benchmarking can be used as a tool to prevent serious overruns on cost and scheduling for some of the megaprojects. Industry research indicates that megaprojects in general (Merrow, 2011) and nuclear projects in particular (Locatelli, 2018) are prone to such overruns. While this research is focused on overruns of new-build activity, some authorities (such as in the United Kingdom)

have extensive new-build scope as part of their decommissioning plans. Some decommissioning project cost and schedule outcomes have already illustrated considerable overruns, by as much as an order of magnitude on cost, and decades on the schedule.

Programme and project teams

Programme and project teams have as much interest as executive decision makers, and authorities and regulators, in reliable cost and schedule estimates. Reliable estimates help formulate robust project execution plans, and help develop accurate scopes of work for the supply chain (the supply chain as a stakeholder is discussed in the following section).

In addition, programme and project teams are interested in a further level of detailed insight that cost benchmarking can provide. Teams involved in the early, shaping step of the project life cycle focus on identifying and selecting options for further development. This entails, firstly, widening their analysis of the ranges of alternatives, then narrowing and rejecting options until a single, preferred alternative is evident, and this latter alternative is brought forward for approval. Such "optioneering" activity is crucially supported by cost benchmarking, not only because it informs the cost and schedule estimate ranges of alternative approaches and thus their relative merits, but also because it compares the approaches directly. Furthermore, in seeking to understand why an estimate varies from one seemingly analogous project to another, project teams gain insight into alternative approaches and methodologies that might optimise their own plans, and thus identify superior approaches.

Whereas decision makers, authorities and regulators are interested in cost benchmarking and schedule estimates of the project as a whole, programme and project teams have much to gain from benchmarking detailed aspects of the cost and schedule. For example, simple databases of "norms" (typical costs or cost ranges for particular cost items) to explain typical costs for equipment and materials can help inform base cost estimates. Cost estimate and benchmark data presented in the form of "ratios" (estimated cost in relation to typical cost value or ranges) can help identify whether a system is over or under-engineered.[1] Benchmarking ratios cannot reveal such issues directly, but analysis of deviations from other project ratios can stimulate programme and project team members to ask probing questions that lead to such revelations.

Cost benchmarking for programme and project teams can thus be of a different kind than that for executive decision makers and authorities and regulators. It occurs throughout the project life cycle and not only in association with decision gates when approval is being sought for estimates. Cost benchmarking occurs at the detailed level, not just the macro level. Furthermore, it is expressed in a myriad of ratios, trends and discontinuities. In some industries, it has been found that programme and project teams might rely on a set of benchmarking tools and data that are different from those used by executive decision makers. The interface with cost benchmarking tools and products by executive decision makers and by programme and project teams needs special attention in order to ensure that the same underlying information does not give rise to apparently contradictory findings about the status and health of projects and programmes when used in different contexts.

A case study from Sweden illustrating the interaction between cost benchmarking, and project governance and delivery tools, is presented in Appendix A.

1. For example, a relatively high ratio compared to other similar examples could reveal an inefficient (over-engineered) design on the one hand, or a relatively low ratio might suggest an insufficient attention to detailed requirements (inadequate design) on the other hand.

Supply chain

Suppliers need to have a keen understanding of the levels of uncertainty and risk in order to correctly price their work and promise delivery timescales. Typically, this occurs in the context of a competitive bidding process. In addition, suppliers may be invited by programme and project teams to create cost and schedule estimates upon which owner/operator teams will rely.

The owner/operator project control function might sometimes create an integrated project team with the supply chain, integrating suppliers' process of estimation into the project as a whole. The observations made above about the importance and added value of cost benchmarking data and tools for programme and project teams apply equally to the estimating teams in the supply chain. In addition, suppliers as entities can derive added value from cost benchmarking by demonstrating the robustness of their estimates in the bidding process, and thus the commercial viability of their tenders. The specific types of value added include: being able to provide greater certainty of cost and schedule outcome; being able to negotiate more fairly any incentivisation and penalty clauses associated with a contract; and being able to optimise bids by comparing and contrasting design and project execution characteristics with analogous projects.

Because of its role in the bidding process, the supply chain tends to regard benchmark data as a competitive advantage and to be unwilling to share it with other entities. These supply chain concerns will be discussed further in subsequent chapters, in the context of barriers to sharing sensitive information and how these might be addressed.

2.2. An example of the potential for added value

This section outlines an example of how the United Kingdom Nuclear Decommissioning Authority (NDA) used project-level (i.e. the whole project) cost benchmarking to inform executive decision makers on the costs of decommissioning NPPs.

In 2013, the NDA project controls contract supplier recognised that consistent data capture from current decommissioning projects would improve the estimation of costs and scheduling for future projects, enabling better decision making. By adopting consistent methods of data capture, the UK nuclear decommissioning industry would be in a better position to share and utilise the information available. The scope of the exercise included analyses of two projects at the Bradwell and Dungeness nuclear power plants, which were then either at or near completion. By analysing these past projects and understanding the scope, cost drivers and project specific "premiums", the hope was that greater certainty of outcome would be achieved on future projects.

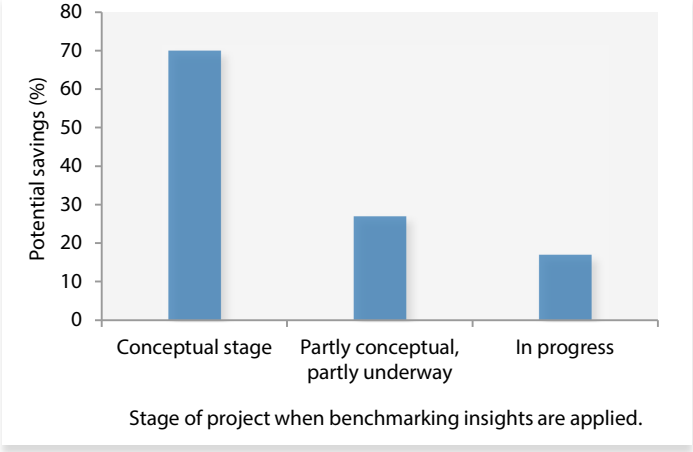
This work captured the following types of information:

- the scope of work performed;
- the original cost estimate in a standard cost breakdown structure and the actual cost outcome;
- a variance analysis that identified the reasons why costs changed between the original cost estimate and the actual cost outcome;
- metrics appropriate to the nature of the project that could form the basis of the cost norms for use on future projects;
- the cost "norms" against the identified metrics.

The results from this analysis suggest that consistent application of cost benchmarking tools could present opportunities for potentially large cost savings in relation to future projects, in applying the lessons learnt from those earlier projects. The study showed that the greatest potential savings could be realised if the benchmarking insights were applied early in the project development (i.e. at the conceptual design stage), and that the potential

savings diminished if the insights were applied later, as the project planning advanced, or when the project was underway. Figure 2.2 indicates the magnitude of potential savings foreseen by the NDA at the time, all of which could be achievable if the insights obtained through the use of cost benchmarking techniques were effectively applied.

Figure 2.2: **Potential savings on future projects identified by the NDA from the application of cost benchmarking techniques**



Source: NDA.

In 2015, the NDA commissioned a further benchmarking study in order to build further on the potential identified in 2013. The study focused on data from the NDA Estate portfolio of recent decommissioning with historical data from the NDA's Project Memory Guide and the United States Department of Energy. A standard proforma structure was developed to capture the facility size, cost and schedule. The project data was broken down into the stages of studies, design, construction and commissioning. Nine facility types were identified, based on construction methods and the complexity of equipment, with less emphasis on the facility function. Projects were categorised according to these nine facility types and direct comparisons were drawn for whole-project estimation. With data input from ~1 000 projects, the NDA was able to gain sufficient confidence to make a significant reduction in the nuclear provision for projects across the NDA's estate. The database fell into disuse after an attempt to transfer ownership to another arm of the UK government. One of the lessons learnt from this study is that clear long-term ownership of data is as important as the initial gathering of the data itself for the ultimate success of a cost benchmarking approach. This theme will be explored further in Chapter 4.

The NDA has also experimented with other benchmarking approaches. In recent years, the construction of a second independent cost estimate for major projects has been attempted, using cost norms from other industries devoid of the "nuclear premium" thought to exist in the United Kingdom. This approach has been found to be of variable utility, and is inherently expensive, although it did provide insight, at the line-item level within project cost estimates, into the root causes of variances, while providing suggestions for cost optimisation. The NDA has most recently experimented with using third party suppliers to benchmark major capital projects at the project level. The approach has been insightful, but is hindered by limited availability to a robust dataset of analogous projects accessible to third parties. The NPPs for which the NDA is responsible are mainly of the Magnox type, and the approach to sharing cost data on decommissioning between these NPPs has, to date, consisted of placing the entire fleet of Magnox reactors into one organisational unit in order to maximise the opportunities to apply lessons learnt and share cost data.

Chapter 3. Approaches

This chapter discusses some approaches used for cost benchmarking in other industries and how these might be applied to cost benchmarking for decommissioning NPPs.

3.1. Approaches to benchmarking in other industries

Historically, cost benchmarking has always been part of the approach used during major projects: the questions "how much will it cost?" and "how long will it take?" have always been informed by comparisons to other analogous projects. The last decades of the 20th century saw the greatest innovation in benchmarking approaches, enabled by advancements in information technology that allowed more effective sharing and structuring of data, as well their normalisation. This innovation also followed a post-war investment boom that generally disappointed investors in terms of project outcomes not meeting expectations. The consistent failure to deliver projects on time, within budget and to specification, led to considerable investment in techniques to better match the estimates with the outcomes.

The degree of experience with, and sophistication of tools to support, cost benchmarking varies between industries. This chapter examines approaches developed for oil and gas, shipbuilding and civil construction.

The oil and gas industry

The oil and gas industry has long benefited from services that benchmark project costs, schedules, the scope of projects and even project maturity at stage gates for new-build capital investments, but only lately have these services been extended to the decommissioning of such facilities. The services to support decommissioning estimates for offshore facilities in the Gulf of Mexico are generally more advanced than for decommissioning in the North Sea, reflecting the cycle of maturity since older Gulf of Mexico assets were being taken out of service earlier.

Despite the decommissioning of North Sea offshore oil and gas facilities still being in its infancy, the capacity that the industry already has to benchmark such initiatives far exceeds the capability of the nuclear industry to benchmark its own decommissioning programmes, which are at similar, early stages of development. This lack of capacity in the nuclear industry underlines the enormous potential for applying cost benchmarking approaches to its decommissioning projects, along with the possibilities for learning from the offshore oil and gas sector when doing so.

Oil and gas cost benchmarking is served principally by three third party suppliers in the private sector. Two of these offer benchmarking services covering mainly surface facilities and the third offers benchmarking services focusing on subsurface wells. The two providing benchmarking services relating to surface facilities each oversee a consortium in which more than half of the industry participates to share benchmark data. Many of the "supermajor", international oil companies participate in both forums, and some seek to benchmark their projects twice using the data available from each supplier. In addition, certain jurisdictions host governmental sources of cost benchmark data (for example, the United Kingdom regulator, the Oil and Gas Authority) to complement

offerings from the private sector, ensuring a like-for-like data set within a certain geography and regulatory framework.

Whereas participation in private sector benchmarking consortia is voluntary at the enterprise level, once an enterprise joins a consortium, individual project participation becomes mandatory for members, whereby projects may use the database to inform their estimates, but they must supply their actual outcomes at project closure to help others in the consortium. Participation in governmental benchmarking regimes is often mandatory, as a pre-requisite for governmental approvals, and thus governmental databases can be useful repositories of holistic data sets.

Oil and gas benchmarking cost datasets are typically limited in scope to oil and gas initiatives, with little or no sharing of data between this industry and other industries. This is the case by design, in order to guarantee that the operators contributing data have a certain level of control of their usage. At the same time, there are no intrinsic limitations such that the industry could not learn from another data set: for example, the construction of a hull for a floating production storage and offloading vessel in oil and gas may have many similarities with the hull of a super tanker in the shipbuilding industry.

The oil and gas industry conducts cost benchmarking at both the project level and the activity level, and some of the commercial benchmarking organisations focus on delivering services relating to one or another of these types of benchmarking. Project-level benchmarks are often demanded by decision makers and regulators as part of the approvals process, whereas activity-level benchmarks are used by project teams to refine design criteria and project execution approaches (see Section 3.2 below).

In the oil and gas industry, the cost data available for the benchmarking of decommissioning activity is less plentiful than that for new build. Nonetheless, the same tools and techniques used for decades to benchmark new build are now being extended for use in the case of decommissioning activities. Although the industry suffers from a relative lack of data related to decommissioning, with some data richer from certain basins than others, it has not stopped the industry from normalising the data for use in one part of the world to another, e.g. normalisation of data from the Gulf of Mexico for use in the North Sea.

Commercial and defence ship building

Individual commercial ship builders have the benefit of significant, historical data capture, which informs their norms and estimating approaches. Despite the competitive nature of commercial ship builders, these companies have embraced the benefits of sharing benchmark data across the industry in a drive for effectiveness and cost reduction. Commercial, civilian ship builders share data anonymously through First Marine International (FMI). FMI maintain the data set and have developed the algorithms to normalise the data and understand the variant factors (complexity, regulatory environment, etc.).

In response to concerns regarding the performance of UK naval projects, and in a UK market with limited competition, the UK Ministry of Defence has also commissioned the FMI to benchmark naval projects. The use of cost benchmarking in defence shipbuilding has expanded and now encompasses Australian and US projects.

Civil construction

The International Construction Measurement Standards Coalition (ICMSC) is a group of more than 40 professional and not-for-profit organisations from around the world, working together to develop and implement international standards for benchmarking, measuring

and reporting construction project cost.[2] To this end, the ICMSC has produced the International Construction Measurement Standards (ICMS) (ICMSC, 2017). The ICMS is a cost classification and reporting system, which aims to provide global consistency in classifying, defining, measuring, analysing and presenting construction costs. The first edition of ICMS focuses on capital costs; however, future editions of ICMS may also incorporate other matters such as costs in use.

A survey of the members of the Global Alliance for Buildings and Construction (GABC) was published by the Royal Institution of Chartered Surveyors (RICS) in November 2017 (RICS, 2017). The purpose of the survey was to investigate what type of construction data is collected by whom, where and for what reason; and also to examine data collection and use patterns. The survey identified a series of key challenges in relation to better data capture and management, such as the lack of a central storage location, non-harmonised data collection formats and data reporting obligations, overall data availability and accessibility, and data reliability. The analysis concluded that, in terms of effective data capture and subsequent management, the sector still has some way to go. While there is an encouraging number of good practice examples and public and private initiatives, the overriding message of the survey findings is that fragmentation and silo-thinking in this sector has affected the way that data are handled in the sector. Finally, the report also provides guidance as to how some of the challenges identified may be potentially overcome, highlighting the benefits and opportunities that arise from a more consistent and coherent approach to data and information collection, as well as management for individual stakeholders.

In March 2018, the results of a series of industry workshops, with the objective of identifying the incentives for, and barriers to, sharing cost data, were published by RICS (RICS, 2018). These results noted the increasing difficulties in collecting consistent data at the required level of granularity, which likely stem from changes in the approach to contracts; a growing reluctance from the industry to give away what is increasingly seen as a valuable commodity – which is often protected by intellectual property rights (IPR) – and clients' insistence on confidentiality, particularly in the private sector. Intriguingly, the findings highlight that the benefits of sharing data seem to be well recognised by clients, consultants and, to a lesser extent, contractors. Moreover, they suggest that the willingness to share data appears to be proportional to the perceived benefits. The report nonetheless questions whether this apparent recognition of the value of sharing data is a true reflection of the actual appetite for doing so. It appeared from the workshops that there was general agreement across the industry that the ICMS could act as a catalyst to change attitudes. The ICMS could thus be the appropriate vehicle through which the process of cost collection and analysis is standardised.

3.2. Common features of other industry approaches

The examples discussed above highlight two broadly different approaches that might be taken in cost benchmarking:

1. Project level: a comparison of overall cost and scheduling for one project with the overall cost and scheduling for another. This technique is offered by Independent Project Analysis Global (IPA Inc.) for oil and gas and process industries, and by the FMI for shipbuilding. The approaches are typically aimed at informing the decision executive, as well as the authority and regulator stakeholder groups.
2. Activity level: a comparison at the line-item level within a project's cost and schedule estimate – i.e. comparison of one activity of the project against a similar activity in another project – and aggregation of the results. Turner and Townsend, the ICMS, IPA Inc. and the FMI offer this type of analysis.

2. Description adapted from https://icms-coalition.org.

Cost benchmarking approaches in these industries have some shared characteristics. These include:

- a horizontal collaboration between organisations, and across geographies between entities that may otherwise be competitors;
- a vertical collaboration between governments, operators and the supply chain to share data in managed ways;
- the centralisation of the structured records of project outcomes into databases;
- facilitation by third party entities that provide value-adding services to consortia of participants, which may range from agreeing formats for making comparisons to actually managing and analysing data provided by members.

In the examples provided above, the involvement of the private sector in providing the benchmarking services is noteworthy. Evidently, the industries concerned have found a way not only to overcome barriers to sharing data, but they have also developed such a level of trust that the private sector has been invited to host the data on their behalf. In this context, the RICS analysis described above (RICS, 2018) highlights a number of critical issues for establishing databases equally applicable to cost benchmarking for nuclear decommissioning, as represented in the following questions:

- How can clients and their supply chains be incentivised to collect data that is comprehensive and robust, while properly describing the context?
- Who should pay for the cost of data collection and analysis?
- Which entity or entities should take the lead in setting up, managing, offering quality assurance and analysing the data repository? And how should it be funded?

Many factors contribute to making direct comparison of projects difficult during a cost benchmarking exercise. Projects occur in different contexts, for example they may vary in complexity, may be novel, operate in different regulatory environments, encounter different labour costs and industrial relations arrangements, utilise different currencies, and they may have access to labour with varying levels of skill and training, experience with complex technology, etc. Approaches to address these benchmarking challenges in such contexts have been adopted by other industries, and include:

- techniques to present/store data in a consistent format;
- agreement to use a standard work breakdown structure/cost-reporting format;
- specific methodologies to compare and assess non-equivalent data sets or non-normalised data.

The use of standard, work breakdown structures, cost breakdown structures and product breakdown structures greatly simplifies cost benchmarking. The *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* report provides exactly this type of common reporting structure for NPP decommissioning costs (NEA, 2012). The International Atomic Energy Agency (IAEA) has in fact adapted the ISDC for application in research reactor decommissioning projects (IAEA, 2017).

Approaches to cost benchmarking by other industries considered in this report suggest that benchmark databases are a key enabler for providing the added value sought by stakeholder groups, a subject that will be further discussed in the following chapter.

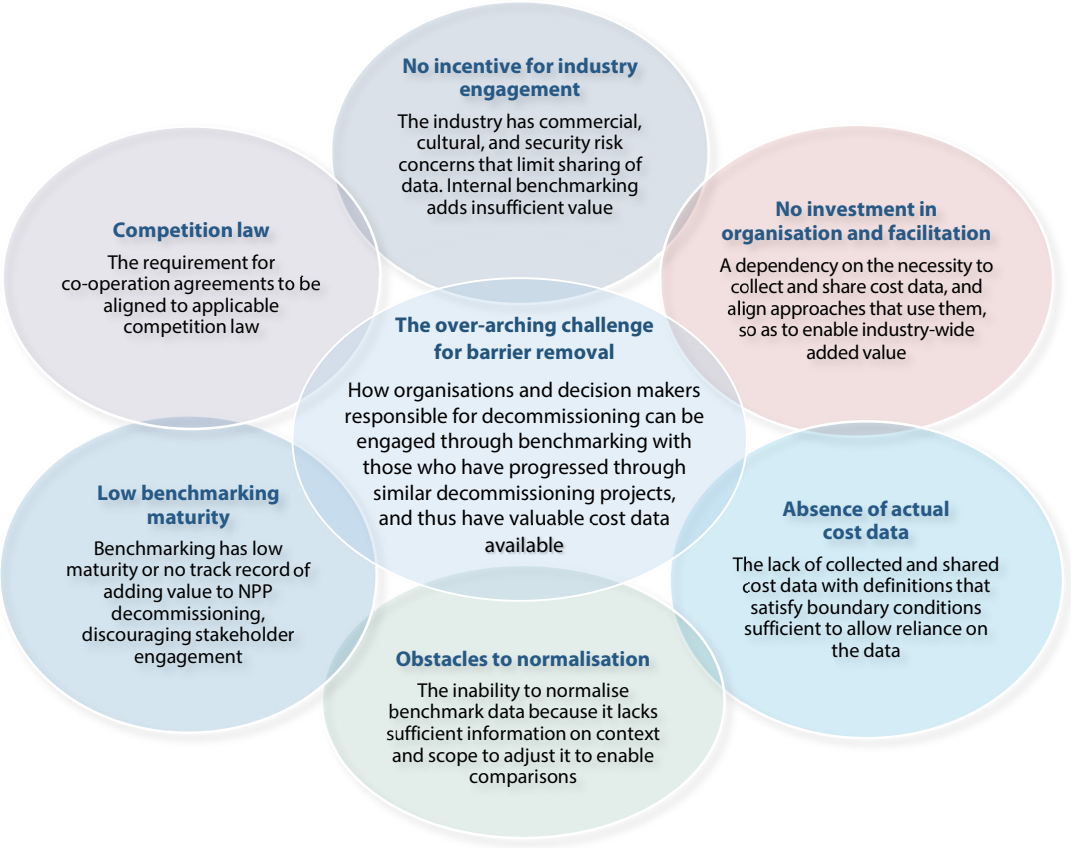
Chapter 4. **Barriers and enablers**

4.1. **Cost benchmarking approaches – Barriers**

Barriers to the introduction of cost benchmarking in the decommissioning of nuclear power plants (NPPs) mainly result from a lack of collected data on actual costs, as well as perceived obstacles to sharing this data with others. Enabling the removal of these barriers is thus essential to introducing cost benchmarking approaches and to achieving the added value described earlier in this report. In order to overcome these barriers, it will be necessary to address the apparent absence of an appropriate organisation within the nuclear industry, which will ultimately be needed to enable cost benchmarking and to facilitate the sharing of data.

This chapter discusses the interrelated barriers to cost benchmarking. These barriers are common to costs at both the project level and the activity level. Figure 4.1 illustrates the nature and interrelated character of such barriers.

Figure 4.1: **Barriers and the overarching challenges for their removal**



As these barriers are interrelated, each one needs to be removed in order to allow the cost benchmarking to deliver its full, potential value. Each of the barriers is discussed in more detail in the following subsections. Potential enablers for the removal of the barriers, as well as the overarching challenges for barrier removal, are discussed in Section 4.2.

Barrier: No incentive for industry engagement

The nuclear industry has numerous commercial, cultural, security and risk concerns that act as barriers to sharing cost information with others. Today there is essentially only internal cost benchmarking within organisations, and this is not adding the overall value sought from cost benchmarking. The nuclear industry often describes his reluctance to share data as a fundamental barrier to even engaging in the first, potential steps required to start implementing cost benchmarking across the industry. These industry-specific barriers are summarised at Appendix B.1.

The extent to which nuclear industry actors may be interested in cost benchmarking varies widely. There are those who might want to take the benefits and realise the added value from cost benchmarking, but have little ongoing interest in investing or otherwise collaborating in its development and maintenance. Similarly, there may be stakeholders with valuable data from advanced or completed decommissioning projects, who have no future requirements in this regard and thus little or no interest in collaboration for the benefit of others. In addition, some NPP operators might be more incentivised to focus on nuclear power generation rather than decommissioning of NPPs or radioactive waste management, and they might have little interest in participating in the optimisation of decommissioning costs.

Barrier: No investment in organisation or facilitation

Currently, no organisation or governance has been established or designated to collect and share data in the nuclear sector. And yet any such structure and process must be managed in a way that will meet and satisfy potential stakeholder concerns. It is also necessary to encourage engagement by showing real value and benefits at the different stakeholder levels. Other industries have developed an organisation, governance and facilitation to both enable management of the perceived risks and add value, and there is sufficient evidence to indicate that the nuclear industry can learn and benefit from this experience (see illustration in Figure 4.2).

Barrier: Absence of actual cost data

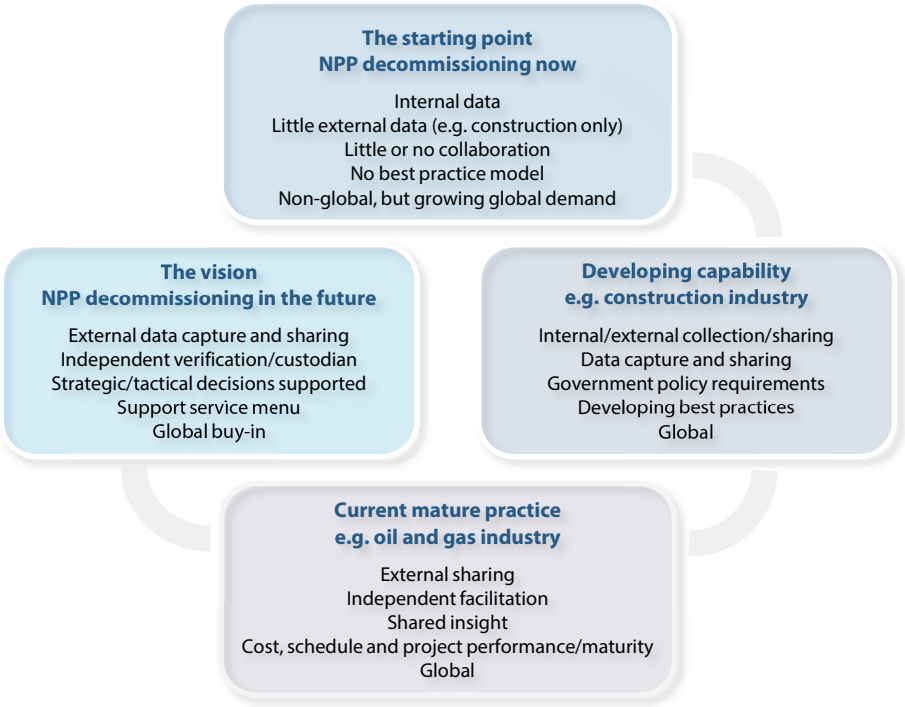
"The lack of cost data from actual decommissioning projects is a major hindrance to the benchmarking and validation of decommissioning cost estimates" (*Costs of Decommissioning Nuclear Power Plants* [NEA, 2016a]).

Actual cost information that can add value when it is made available to others is a crucial aspect of the cost benchmarking process. In other words, it is important to have information on actual costs for projects and activities that have been completed. This might also include records of estimates made at recognised project stages, useful when examining the effect of project and engineering maturity on estimates. Actual cost data needs to be accompanied by a description of the project or activity scope that it represents. This description must describe boundary conditions sufficiently well in order to allow reliance on the cost information definition in the preparation of other estimates, decisions and approaches to proposed decommissioning work and services. Cost data which is provided with this accompanying description, is referred to in this report as "actual cost data", i.e. benchmarks.

There is a general absence of industry shared, actual cost data from NPP decommissioning to support external cost benchmarking. This absence of shared information generally results from few such NPP decommissioning projects having been fully completed. While some project and multi-national data are captured and managed in

specific cases (e.g. within the EU Nuclear Decommissioning Assistance Programme [NDAP]), where such actual cost data exists, its collection and sharing is not widespread. Today, when actual cost data is captured in a comparable, validated and trustworthy form, it is typically held and used within the organisation where it originated to support internal cost benchmarking. Some isolated sharing of cost data does take place, but it is rare. Organisations capturing and using only their own data are fully aware that this internal benchmarking is not delivering the value sought as they are unable to draw on wider experience in seeking to apply lessons learnt.

Figure 4.2: **Organisation and facilitation – Examples of other industries compared to NPP decommissioning (with assumed starting point and vision)**



Barrier: Obstacles to normalisation

"The barrier is the inability to normalise the benchmark data, to a reasonable fit with the subject of the cost estimate, because the benchmark lacks context to enable adjustment" (NEA, 2016a).

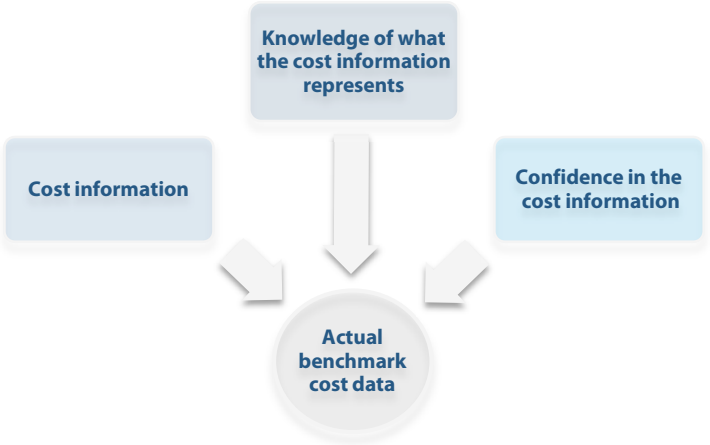
Normalisation, for the purposes of this report, means the process of conversion of actual cost data (facility, project, phase, activity, etc.) that is not directly comparable to the subject of the cost estimate (facility, project, phase, activity, etc.), into data that is comparable. Normalisation allows assumptions and associated risks of the comparison to be identified.

Normalisation also enables like-for-like comparison and alignment of cost data. Without it, the comparability of data would be misleading, presenting significant risk for the user. Normalisation is about the need to account for the natural differences between projects or activities – differences in what the actual benchmark cost data represents (facility, project, phase, activity) when compared to the subject of the cost estimate (facility, project, phase, activity). This need to account for differences can also apply to the potential use of benchmarks for historic end-stage/phase estimates of probable cost out-turn ranges

to check the out-turn forecast of a project, where assumptions made in the estimates should also be understood.

Actual cost data needs to be reasonably aligned to the subject of the cost estimate. This actual cost data must provide the user with knowledge (including boundary conditions) and confidence sufficient to identify the differences between the subject and benchmark projects and activities, as well as the risks in terms of the conclusions drawn from comparisons made. The quality of normalisation will inform the quality of the outcome from the cost benchmarking (see Figure 4.3 below).

Figure 4.3: **Benchmark components enabling the normalisation of cost data**



Actual cost information without this supporting knowledge and confidence is a barrier to normalisation, and in turn to introducing cost benchmarking approaches, a barrier that was already identified in the NEA study *Costs of Decommissioning Nuclear Power Plants* (NEA, 2016a) as follows:

> The diversity of views between and within countries, which are all boundary conditions for establishing cost estimates, explains why benchmarking of decommissioning programmes and projects is very difficult, while comparison is possible and recommended for similar activities or project components … lessons must be drawn from completed projects to better understand the cost drivers which help define priority areas and uncertainties for cost estimates. In case the diversity of boundary conditions does not allow real benchmarking from one country to another, comparisons might nevertheless be possible for specific activity or project components.

Normalisation at the whole project level or the activity level requires a degree of knowledge about the benchmark, and has already been examined by the NEA study *The Practice of Cost Estimation for Decommissioning of Nuclear Facilities* (NEA, 2015), which concluded that when comparing costs (i.e. benchmarking), *"cost figures should not be taken at face value unless these ten elements and their history are specified in comparative tables"*. The ten elements identified provide a minimum threshold for the knowledge integral to usable benchmark cost data, and these elements are set out in Table 4.1.

Additional information is needed to support the understanding of and confidence in actual cost data. This would include some or all of the following information set out in Table 4.2. Presenting cost data without this additional information runs the risk of limiting the quality of the benchmarking that can be performed, whether this is at the whole-project level or at the activity level.

Table 4.1: **Elements informing the quality of normalisation and comparison**

Actual cost data benchmarks need to be accompanied by:
Scope of work through to the end-point of the site
Regulatory requirements, including details of reporting and clearance levels
Stakeholders' demands
Characterisation of physical, radiological and hazardous material inventory
Waste processing, storage and the availability of ultimate disposal facilities
Disposal of spent fuel and on-site storage prior to emplacement in a deep geological repository
Clean structure disposal and use of the site for new developments
Contingency application and use in the estimates
Availability of experienced personnel with knowledge of the plant
Assumed duration of the dismantling and clean-up activities

Source: *The Practice of Cost Estimation for Decommissioning of Nuclear Installations* (NEA, 2015).

Table 4.2: **Supporting information contributing to knowledge of and user confidence in actual cost data**

Type of information	
Facility/project type	
Scope of work planned	
Scope of work delivered	
Metrics defining the facility/project	
Data defining the facility (e.g. inventory database)	
Timeline (schedule) achieved (overall, and by stage)	
Basis of estimate +	
Structure of estimate +	
Work breakdown structure + (or recognised cost-reporting structure, e.g. ISDC)	
Schedule and uncertainty analysis (historic) +	
Decommissioning process	Principal activities*
	Activity groups*
	Activities*
Cost categories	
Definitions for cost items*	
Project performance information (planned and actuals)	
Facility/project delivery strategy (planned and actuals)	
Procurement strategy (planned and actuals)	
Waste management strategy (planned and actuals)	
End-state delivered (planned and actuals)	
Independent validation of cost information; data is traceable	
Assumptions and boundary conditions* (as below)	
Scope of work through to the end-point of the site	
Regulatory requirements, including details of reporting and clearance levels	
Stakeholders' demands	
Characterisation of physical, radiological and hazardous material inventory	
Waste processing, storage and the availability of ultimate disposal facilities	
Disposal of spent fuel/on-site storage prior to emplacement in a permanent (e.g. geological) disposal facility	
Clean structure disposal and use of the site for new developments	
Provisions for estimating uncertainty and risk – application and use in the estimates	
Availability of experienced personnel with knowledge of the plant	
Assumed duration of the dismantling and clean-up activities	

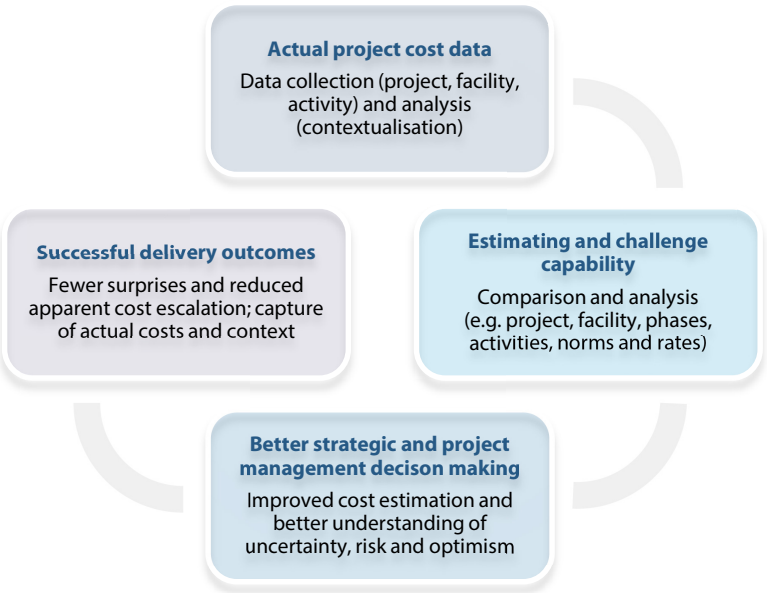
Notes: Items marked with a + are identified in *The Practice of Cost Estimation for Decommissioning of Nuclear Installations* (NEA, 2015), and those marked with a * + are identified in *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (NEA, 2012).

Barrier: Low maturity in cost benchmarking

The nuclear decommissioning industry has not developed enough maturity in cost benchmarking approaches through its experience in applying them, nor has it built a track record of adding value through their application. This current lack of experience and maturity in cost benchmarking discourages stakeholder engagement.

Cost benchmarking develops maturity through an iterative development cycle as illustrated in Figure 4.4. The limited number of examples of fully completed NPP decommissioning projects to has contributed to the lack of maturity in cost benchmarking. With little actual cost outcome data available, and because available data is not currently being shared, projects have become accustomed to constructing estimates without the benefit of external cost benchmarking. Similarly, decision makers have become accustomed to approving projects without any reference to established cost benchmarks. When projects are completed, these projects are not in the habit of sharing their outcomes with others, as they themselves did not originally benefit from the help of others in this regard. The cost benchmarking maturity development cycle outlined in Figure 4.4 is thus broken. Instead, a lack of demonstrable value combined with other obstacles creates a barrier to building the industry support and investment necessary to "kick-start" the development of a cost benchmarking approach and bring it to maturity.

Figure 4.4: **Cost benchmarking maturity development cycle**



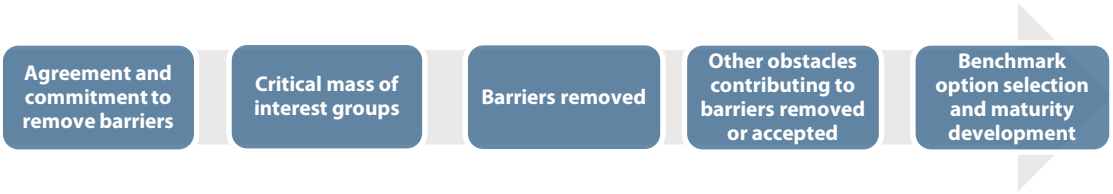
Barrier: Competition law

The requirement for co-operation agreements to be aligned to applicable competition law will need to be accommodated by any organisation of parties who agree to the sharing of cost data and cost benchmarking. The requirements of such alignment requires additional analysis beyond the scope of this report.

4.2. **Cost benchmarking approaches – Enablers for the removal of barriers**

As illustrated in Figure 4.5, some dependencies for being able to develop cost benchmarking approaches currently exist.

Figure 4.5: **Dependencies for benchmarking approach development**

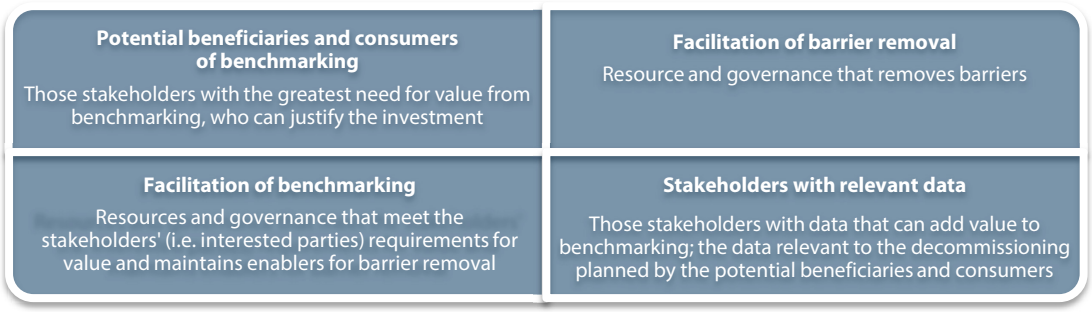


Actual cost data is not yet available to support external cost benchmarking, at project or activity level, with the possible exception of a subset of activities common to non-specialist construction work. The availability of actual cost data is considered a key starting point in the development of cost benchmarking, because it can incentivise and motivate the industry to engage and invest in benchmarking. With data availability and associated industry investment comes the potential ability to conduct normalisation and develop benchmarking maturity. Once the absence of actual cost data is addressed as the starting point for enabling cost benchmarking to develop, then there is still the problem of demonstrating value. This evidence of value is necessary to begin engagement, encourage industry participation, and spur investment to capture and share actual cost data.

The challenge will be engaging organisations responsible for planned future NPP decommissioning in cost benchmarking with those that have progressed through similar decommissioning projects, and so have (or will have) valuable actual cost data to input.[1] In other words: *"How do we get the right people and organisations in a room, who will together agree that benchmarking is a good idea because of the benefits it provides, and who are prepared to make benchmarking happen?"* This is the overarching challenge to enable the removal of barriers.

A "critical mass" of participants and facilitation is necessary to initiate the development of cost benchmarking. This coming together of organisations with the most value to gain from cost benchmarking is considered essential for the development of a viable cost benchmarking approach.

Figure 4.6: **A critical mass for barrier removal and cost benchmarking development**



Also essential is the engagement of stakeholders with data capable of being shared. It is the organisations with the greatest decommissioning challenges in terms of overall cost that can expect the greatest value from benchmarking. The organisations that can justify the investment in benchmarking can form the critical mass to get an initiative started. The beneficiaries and consumers of cost benchmarking are the principal organisations and decision makers responsible for planned future NPP decommissioning, as illustrated in Figure 4.6.

1. An approach to obtaining market and interest group perspectives is set out in Appendix 4.2.

Drivers for the enablers – The likely demand for cost benchmarking

The demand for decommissioning cost benchmarking services could provide the impetus to overcome the challenges of their implementation. Fewer than 20 NPPs have completed the decommissioning process to date and a further 173 NPPs are in permanent shutdown, with varying plans and schedules for decommissioning.[2] Industry estimates indicate that an additional 200 NPPs will be shut down over the upcoming two decades, from the 450 NPPs in operation worldwide today. The demand for cost benchmarking to support improvement in cost estimation and decision making is expected to increase ahead of this planned shutdown of reactors. Potential demand could also be expected from those assessing decommissioning costs when planning new NPPs, and in developing the business cases for such investments. All future NPP decommissioning projects could benefit from the sharing of benchmark data from completed projects and from those for which decommissioning planning is more mature.

The market for cost benchmarking data for NPP decommissioning is therefore considered real, and the countries that might benefit the most are those with the largest number of NPPs. In most countries, the operator or owner is responsible for the decommissioning costs, and thus these operators/owners would be the primary beneficiaries and consumers of cost benchmarking.

In such a context, there is a significant risk that the absence of a demonstrable benefit and value from cost benchmarking prevents or delays the capture and deployment of the actual cost data required to demonstrate the benefit. Stakeholders might choose to rely upon their own accumulated data for detailed cost estimating, or on published ranges (see NEA, 2016a) for overall NPP decommissioning costs. Mitigation of this risk requires the development of value-added benchmarking in the industry, which depends on building a collaborative case and gaining widespread stakeholder buy-in. Stakeholder buy-in should focus on those who will have the ownership of actual cost data produced by ongoing and near-term projects (the suppliers of data), and those with responsibility for near-to-long-term projects (the demand for the data).

Some stakeholder organisations will be on both the supply and demand side of benchmark data, and as such there is a risk that they choose to remain independent from any collaboration, preferring to protect their commercial position. In other words, though the industry would benefit by collectively agreeing to invest in and "trigger" the development of cost benchmarking, there is a risk that gaining buy-in to collaborate in cost benchmarking might be difficult for the owners of data, and those with little or no future requirements for cost benchmarking.

Enablers for barrier removal (a two-stage approach)

Given the interdependent nature of the barriers, they would need to be addressed together, and not individually. Implementation of these enablers should be considered as the first of a two-stage approach to barrier removal. Once these are removed and the critical mass is built, then the more detailed barriers can be addressed (see also Appendix B.1).

The first stage enablers for removal of barriers to cost benchmarking are outlined in Figure 4.7.

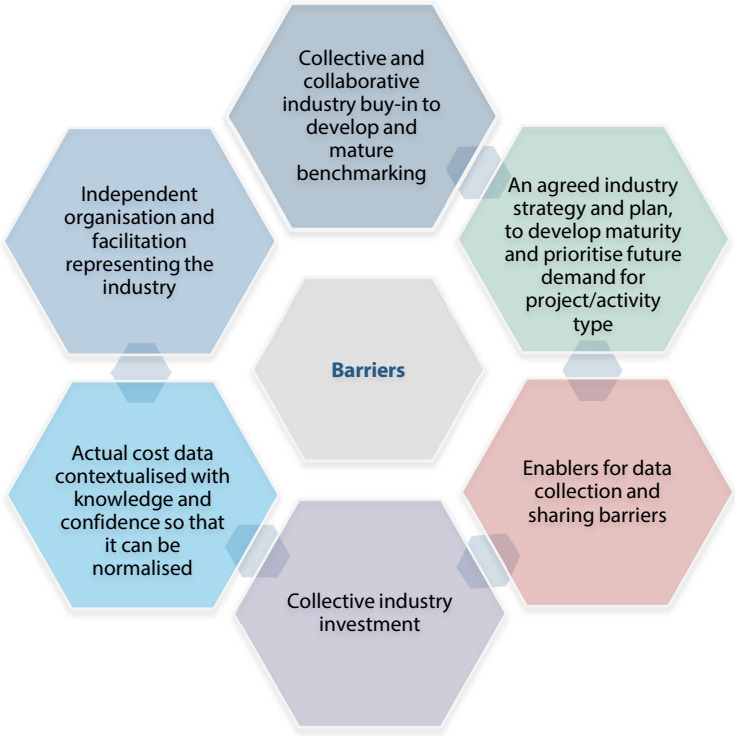
The relative lack of actual cost data in relation to NPP decommissioning is a fundamental issue. Its development is dependent upon delivery and completion of NPP decommissioning projects, from which useful data can be drawn. While the collection and sharing of actual cost data is the fundamental start-point for maturing the benchmarking process, it is unlikely to happen without a collective, collaborative industry approach that

2. Data from IAEA PRIS database, http://pris.iaea.org, accessed 16 April 2019.

would provide a "trigger" for investment in, and conducting of, organised collection of actual cost data.

Furthermore, the demand for, and the optimum time for using such actual cost data (e.g. in assessments of likely future liabilities or for approval of project business cases) is likely to largely precede its availability from completed projects. Many of the projects delivering actual cost data will not be completed in the near term, delaying availability of the data. There is therefore a significant issue for the industry: how to trigger and encourage investment in data collection and sharing today, while not being able to demonstrate the immediate value to many of the potential users of cost benchmarking until a point in the future when well-defined actual cost data would become available? This issue might be addressed by prioritising the collection of data that is of greatest added value to globally planned types of projects, and activities most relevant to the majority of retiring NPPs (e.g. activities that are at the forefront of similar decommissioning projects, and/or with significant repeat elements and activities).

Figure 4.7: **Enablers for the removal of barriers to cost benchmarking**



Enablers: Other industry experience

Lessons learnt and practices observed from other non-nuclear industries provide some relevant insights into a possible way forward for benchmarking NPP decommissioning costs.

A number of examples of enablers for benchmarking in relation to each of the barriers are shown in the tables below. The information presented has been identified from the construction sector (Table 4.3) and from the oil and gas industry (Table 4.4). Where the barrier has been successfully addressed, the status column is green, and where it has been partially addressed, the status column is amber.

Table 4.3: **Examples of benchmarking enablers in the construction sector**

Barrier	Enablers for benchmarking in the construction sector	Status
No incentive for industry engagement	Activity-level benchmarking used to build bottom-up cost estimates for projects. Industry commercially supports the capture of data. Unit rates (e.g. per square metre of facility) applied to early planning. Project or sub-project-level data is used.	Addressed
No investment in organisation and facilitation	Independent organisation (RICS, BCIS) established 50 years; collects, collates, analyses, models and interprets cost information. International coalition to promote benchmarking initiatives globally (ICMS).	Addressed
Absence of actual cost data	Data collected globally through independent sector institution (RICS). RICS makes cost information accessible through data licensing and publications.	Addressed
Obstacles to normalisation	Normalisation is carried out by the organisation accessing the data. "International Construction Measurement Standard: Global Consistency in Presenting Construction Costs" provides a framework against which costs can be classified, measured, recorded, analysed and presented.	Partially addressed
Low benchmarking maturity	RICS Guidance Note, "Cost Analysis and Benchmarking", published in 2013, providing recommended good practice; plans for development of maturity not available.	Partially addressed
Competition law	Agreements aligned to applicable competition law. Cost information accessible through data licensing and publications.	Partially addressed

Sources: *Cost Analysis and Benchmarking* (RICS, 2013); *Global Trends in Data Capture and Management in Real Estate and Construction* (RICS, 2017); *Sharing construction cost data – benefits, challenges and opportunities* (RICS, 2018).

Table 4.4: **Examples of benchmarking enablers in the oil and gas industry**

Barrier	Enablers for benchmarking in the oil and gas industry	Status
No incentive for industry engagement	Industry has considerable experience in cost and schedule challenges in new-build developments. Executive decision makers require industry benchmarks as part of business case approval process. Operators routinely benchmark themselves with regard to project outcomes, with net present value (profit) incentive for better performance readily apparent. Some countries also have governmental authorities that mandate the delivery of cost and schedule outcome data for subsequent use in benchmarking new decommissioning business cases, as part of the review and approval process.	Addressed
No investment in organisation and facilitation	Several, long-established, major independent cross-industry collaboration groups, in which most operators participate (some operators participate in more than one). All groups are managed by private sector enterprises, and most oil and gas majors participate, with their data suitably anonymised. Some major corporates also organise and share their internal data within their divisions.	Addressed
Absence of actual cost data	Large numbers of completed new-build developments have populated and developed the benchmarking systems. Decommissioning data is now being applied into pre-existing working tools and practices. Some differences between geographies limit the utility of data; e.g. decommissioning data more prevalent for Gulf of Mexico assets than for North Sea.	Partially addressed
Obstacles to normalisation	Very few: normalisation typically performed in a standardised manner based on structured input from operators. The similarity between decision making processes among operators allows for relatively easy comparison, not just for whole-project outcomes but for cost and schedule at various stages within projects.	Addressed
Low benchmarking maturity	Benchmarking mature. Consortia have developed to perform value-adding services around basic cost and schedule benchmarking; for example, the undertaking of industry studies on areas of common interest; and the benchmarking of project maturity at stage gates. Some major international oil companies mandate use of maturity assessment by third parties as part of their internal decision making process.	Addressed
Competition law	Agreements aligned to applicable competition law by the collaboration group managers and participants.	Addressed

The above descriptions from other industries of example enablers for cost benchmarking suggest that some key enabling or desirable characteristics will need to be considered to support a range of options for initiating value-added cost benchmarking for NPP decommissioning (see summary in Table 4.5).

Table 4.5: **Characteristics that need to be considered to support options for cost benchmarking NPP decommissioning**

Type of enabler	Contribution
Commitment: Industry buy-in to collaborate and invest in development	A collective alignment recognising the benefits and value needed, and common agreement to develop cost benchmarking maturity
The right stakeholders: Principal stakeholders are those with strongest potential demand for value, and those who can supply the actual cost data fitted to the demand	Input to the benchmarking process, especially data
Organisation and governance: A clear governance for engaging in and managing the process and procedure of cost benchmarking	A framework (structure, process, procedure) for data collection, sharing and cost benchmarking, which addresses the stakeholder issues and barriers
Independent facilitator/managed service provider responsible for data collection and sharing – collects, collates, analyses, models and interprets cost information	Resources to implement cost benchmarking to support governance and deliver independent services to meet stakeholder requirements; hosting of benchmark data; normalisation of data; structuring and anonymisation of data
Demonstrable value-adding outcome	Monitoring and capture of lessons learnt to demonstrate that the benefits sought are being delivered, and maturity is developed

4.3. Collecting and sharing data – Barriers

What form of data is required?

As discussed in Section 3.2, to provide value to the different stakeholder types identified, cost benchmarks could represent two principal types or levels:

- Project level: *Whole-project phase estimate ranges*, accompanied by actual whole-project out-turn.
- Activity level: *Actual cost information* at the sub-project, facility and activity levels (e.g. at ISDC levels 2 and 3).

To add value, both of these levels of benchmarking need to be accompanied by the knowledge and confidence in what the estimated and actual cost represents. When combined together in a form to allow normalisation, the cost information, knowledge and confidence become usable benchmarks.

In this context, the cost benchmarking data required provide the information needed to challenge and to justify decisions to secure funding. The data can be used to underpin the basis for the decommissioning plans and budgeting of the baseline cost. It is only through providing the necessary data that cost benchmarking will be able to provide the value sought by the different stakeholder group audiences for these two approaches. Different levels of actual cost data are required to support delivery of project-level and activity-level cost benchmarking. The different levels of cost data required are summarised in Table 4.6.

Table 4.6: **Cost data requirements for project-level and activity-level benchmarking**

Actual cost data required to support whole-project level cost benchmarking	Actual cost data required to support activity-level cost benchmarking
Facilities and projects	Facilities and projects
Project stages	Project stages
Record of estimated cost ranges	Record of estimated cost ranges
Principal activities*	Principal activities*
	Activity groups*
	Activities*

Note: * indicates an item identified in *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (NEA, 2012).

Although actual cost data is required, because it represents a project that has developed maturity and delivered a defined end-state, there is significant value to audiences understanding the path to maturity since it leads to an understanding of the lessons learnt from experience in similar projects. The experience will be in the form of cost out-turn ranges estimated at defined stages in the project lifecycle, compared to the actual cost out-turn. In this case, benchmarking is of particular, potential benefit to the executive decision makers.

The supporting information requirements of both actual cost data and estimated whole-project cost ranges are extensive. Collecting and sharing such detail assumes that those who generate and own the data are prepared to invest in their capture in a coherent usable form, such as the ISDC reporting format or other aligned work and cost breakdown structures. Absence of a common reporting structure is considered a barrier, as it would hinder the collection (supply) of cost data, with appropriate supporting information.

The requirement for data collection and sharing

Data collection and sharing is a critical factor for benchmarking. With other enablers, it is fundamental to start the unlocking of value from, and development of maturity in benchmarking.

The requirement is to capture the actual cost data, and historic estimated whole-project data on probable cost ranges. This data collection and sharing must satisfy demand, deliver added value and satisfy stakeholder sensitivities.

Some actual cost data collection is practised within individual stakeholder organisations. However, evidence suggests that the interpretation of the actual cost data is often problematic as a result of the absence of context in the form of supporting information. This absence of data can be linked to a lack of disciplined and structured data capture but also to knowledge loss ("poor corporate memory") within organisations dealing with very long-term projects. A disciplined, clearly governed system of actual cost data capture and management is essential to data collection and sharing.

4.4. **Collecting and sharing data – Enablers**

Removing the barriers for data collection and sharing

The agreement, investment and co-operation of stakeholders necessary for the removal of barriers to cost benchmarking will need to be reinforced by an approach specifically designed to remove barriers to data collection and sharing. In other words, enabling the removal of some or all of the particular barriers to data collection and sharing cited by industry will be essential (see Appendix A).

The task of enabling the removal of these data collection and sharing barriers, as well as other concerns, should not be underestimated, and plans should fully recognise the significant challenges involved.

This assessment has considered barriers in turn and taken lessons learnt and observations from other industry practice. It has categorised each barrier by its "remove-ability" and identified potential options for removal of the individual obstacles. It has been observed that some barriers cannot be removed and will remain confounding factors, i.e. things that cannot be controlled or eliminated, and these barriers might remain detrimental to cost benchmarking outcomes.

Considerations for data collection and sharing to support value-adding benchmarking

Many risks are involved in establishing and managing the data collection and sharing process. The principal risks identified in this assessment are summarised in Table 4.7.

Table 4.7: **Considerations for data collection and sharing**

Risk – "There is a risk that…"		Impact
Stakeholder buy-in	The demand for actual cost data is not understood and the supply is not/cannot be aligned to the demand	Approach not aligned to the market/industry
	The market is not convinced of the benefit until this is demonstrated, and investment to kick-start development is insufficient	Little engagement or support to establish approaches that remove the headline barriers to benchmarking
	There are no institutions and facilitators prepared to invest in developing an approach because of the low maturity base/perceived lack of benefit	Rules out options that are working in other industries
	The timeline and investment to realise benefit is significant	Initiatives stall or fail to advance
	A common approach to governance cannot be agreed across industry stakeholders (suppliers and users of data) – insufficient removal of barriers	Initiatives stall or fail to advance
	Expectation for collection and sharing, and the development of maturity and release of added value, is too high – turning off interest and investment	Initiatives stall or fail to advance
Data collection	The sources of data are limited, constraining the growth of data collection such that it cannot support the demand, and so maturity development is slowed	Limited usefulness of collected data.
	The actual cost information currently available for collection cannot be contextualised (i.e. with knowledge and confidence), and is not usable	There are little usable data
	The historic estimates of ranges and actual out-turn for completed facilities/projects is not available or cannot be contextualised	There are little usable data
	The actual cost data collected is not convertible to the selected reporting/cost breakdown structure, and cannot be aligned to marks	There are little usable data
	No agreement can be reached on a common cost breakdown structure; there is no incentive to align, e.g. because the benefit is long term	There are little usable data
	The actual cost data is not validated or independently assured and is perceived as carrying risk that outweighs the potential benefit	The benefit is questionable and use could build in additional risk – loss of credibility

Table 4.7: **Considerations for data collection and sharing** *(cont'd)*

Risk – "There is a risk that…"		Impact
Data management and sharing	There is a very large volume and complexity of actual cost data with many variables, assumptions, uncertainties and risks requiring management	A database will be required to manage and allow interrogation, and sharing of the cost data
	The management and sharing of collected data is informing business critical decisions; transparent assurance of the model and outputs is required	Agreement across industry would be potentially onerous
	Shared actual cost data cannot be sufficiently interrogated and normalised by the stakeholder users leading to credibility issues	There are little usable data
	The data shared is so heavily qualified or caveated that their value becomes questionable	Credibility and reputational issue
	Stakeholders become dissatisfied with the sharing service and/or require market testing to satisfy procurement requirements	Flexibility to re-compete is needed

Is a database required?

Less complex options for cost benchmarking might operate with a simple spreadsheet collection and sharing tool, or the mutual publication of reports. More advanced types of cost benchmarking usually involve the building of a database, in particular one that is suitably assured as a business critical model. Lessons from other industries show that the complexity and volume of data collected, the ability to accumulate, maintain and interrogate it over a significant period, and the provision of online access, will necessitate a database. The barriers for participation in terms of commercial and security sensitivities also point to a database solution with appropriate physical and cyber protection.

Advantages and disadvantages of using a database to collect, manage and share actual cost data are summarised in Table 4.8.

Table 4.8: **Cost databases: Advantages and disadvantages**

Advantages	Disadvantages
Control – e.g. error management	Complexity
Data analysis and management	Design and development
Complex search queries	Significant resources
Multiple users	Upfront and ongoing financial resources
Displaying summary datasets	Maintaining security – risk; location; data integrity
Data summary reports	Compatibility
Repetitive data sequences	
Complexity	
High volume of data handled > spreadsheets	
Scalable database architectures for future growth	
Data integrity	
Speed of dataset manipulation	
Stable control – access and user restrictions/records	
Efficiency	

4.5. Enabling cost benchmarking data collection and sharing – Options

Data collection and sharing is an integral part of the cost benchmarking option selection. Some preliminary overarching considerations are identified in this regard for a cost benchmarking strategic business case in Table 4.9.

Table 4.9: **Preliminary considerations informing cost benchmarking, data collection and sharing options**

	Set cost benchmarking strategy, which data collection and sharing is required to support	Define the scope of data collection/sharing
Cost benchmarking strategic business case	• overview; • strategy and aims for benchmarking; • existing arrangements; • business (market needs and demand); • scope of benchmarking (service).	• define the subject cost estimates that the stakeholder demand for benchmarking identifies – in terms of facility, project, principal activity, group activity and activities; • prioritise the data by type, and develop a (phased) plan for capture; • define the actual cost data and the information that will support and contextualise them – i.e. the knowledge and confidence in what they represent; • define where the responsibility sits for data collection and management; • agree a consistent cost breakdown structure appropriate to the above; • consider support and technology to collect, manage and share the data; • define the required validation and assurance of data.

Summary options for cost benchmarking, including data collection and sharing

This assessment explores a range of generic options for data collection and sharing. The options examined range from doing nothing to introducing cost benchmarking arrangements of increasing sophistication and degree of organisation. The options include examples where organisations capture and maintain their own data, and options with an industry-wide, managed service, governed by an independent institution. The outcomes of this analysis are summarised as Options A to F in Table 4.10.[3] A more detailed description of these options is set out in Appendix B.3.

All of these options offer a range of potential advantages and drawbacks. It should be noted that the costs of these options were only assessed in general, relative terms. All of these options will also need to be assessed under competition law, as this issue was not considered in detail as part of this preliminary assessment. Lastly, it should be noted that for all these options, the removal of the initial barriers to benchmarking is assumed. Thus, a more in-depth and thorough analysis of options than was possible in this preliminary review would be needed before proceeding with the choice of any one particular option for implementation. A preliminary period of stakeholder and market consultation should be included as part of a phased roadmap to identify and implement cost benchmarking.

3. The tables are presented in ascending order of complexity with a relative cost ranking from low (green) to high (red). The options are characterised according to a "red, amber, green" (RAG) coding, describing the expected success of the option in removal of the barriers, (red = not removed; amber = partly removed; green = removed).

Table 4.10: Generic options (A-F) for data collection and sharing

Option A: Internal/isolated data collection and sharing								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Internal collection; no external sharing	R	R	R	R	R	R	Low	R

Commentary: Potential isolated internal benefit. No learning or value is added.

Option B: Raw data/isolated data collection and sharing								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for Industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Internal raw data collection; isolated sharing	A	R	R	R	R	R	Low	R

Commentary: Potential isolated internal benefit. No normalisation, learning or value added. Risk from use of raw data.

Option C: Contextualised data/peer group collection/sharing arrangement								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Actual cost data collection; isolated peer sharing	A	A	A	A	R	R	Moderate	R

Commentary: Potential benefit in aligned stakeholder groups. Considered unlikely that data collection/sharing barriers would allow use beyond alliances or formally related organisations.

Option D: Facilitated member group data collection/sharing arrangement – no normalisation								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Actual cost data collection and sharing by 3rd party	G	A	G	A	G	A	Moderate	A

Commentary: Potential benefit in aligned stakeholder groups. Stakeholders carry the normalisation risk.

Option E: Facilitated industry collection and sharing arrangement – Data published with no normalisation								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Managed collection, sharing and benchmark service	G	A	G	A	G	G	High	A

Commentary: Potential benefit in aligned stakeholder groups. Stakeholders carry normalisation risk.

Option F: Rich functionality with facilitated member group collection/sharing arrangement and normalisation								
	Supports removal of the headline industry barriers to cost benchmarking?							
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation	Satisfies added value being sought?	Relative order of cost	Rating
Managed collection, sharing and benchmark service	G	G	G	G	G	G	High	A

Commentary: Potential benefit in aligned stakeholder groups. Stakeholders trust in third party data sharing and normalisation.

Note that each of the options C to F assume the removal of the initial barriers to cost benchmarking. The first stage towards enabling this removal is that the right stakeholder organisations are brought together to form a critical mass, agreeing that cost benchmarking will add benefit. This barrier removal remains a significant risk to implementation of these options, and the timescale for implementation of cost benchmarking. A preliminary period of stakeholder and market consultation should therefore be provided for as part of a phased roadmap to identify and implement cost benchmarking. An approach to this type of consultation is outlined in Appendix B.2.

Chapter 5. Conclusions and recommendations

5.1. Summary of findings

Cost Benchmarking for Nuclear Power Plant Decommissioning is intended to provide policy makers, regulators, strategy and decision makers with a preliminary description and analysis of the cost benchmarking practice and methodology in the context of decommissioning nuclear power plants (NPPs). It therefore discusses approaches to cost data sharing and analysis, as well as the development of cost benchmarking approaches that could be implemented for NPP decommissioning, taking into account related developments in other branches of industry.

Preliminary analysis presented in Chapter 2 concerning the potential added value of cost benchmarking suggests that a variety of stakeholder groups can benefit from such an exercise. The analysis demonstrates that regulators and authorities, as well as executive decision makers from operators and funding bodies, are the stakeholders who would benefit most from project-level cost benchmarking of the cost and schedule. Programme and project teams, and the wider supply chain, would also benefit from activity-level cost benchmarking. This report notes that a degree of overlap may exist between these two clusters of stakeholders. The choice of relevant metrics and the approaches to normalising data, as well as the selection of indicators to be followed, tends to vary depending on which type of cost benchmarking comparison that was deemed most relevant to the particular stakeholders concerned.

The discussion in Chapter 3 of cost benchmarking approaches in other industries highlights the considerable amount of experience with a variety of approaches to cost benchmarking, which could serve as useful models for developing cost benchmarking for NPP decommissioning. More developed cost benchmarking practices in other industries typically involve the creation of standardised international comparisons for project outcomes, supported by centralised databases and by layers of supporting services with varying degrees of sophistication and centralisation. These services are designed to ensure the comparability of data by facilitating consistent inputs and outputs. A variety of organisational models exist, and the choice of a particular model would need to be tailored to meet the objectives of the entities involved. In the nuclear industry, some cost databases and analytical services are currently in place at the national level or within individual organisations. Some data is held at the governmental level, some at operator level and some at the supply chain level.

While the specific focus of this report is on the application of cost benchmarking in the context of NPP decommissioning, the approaches considered here are nonetheless relevant to the decommissioning of other nuclear facilities. Experiences from some other industries suggest that the scope need not be limited to only the cost benchmarking of NPP decommissioning, but that a cost benchmarking service for the decommissioning of nuclear power plants might be broadened to cover a wider range of decommissioning situations, or even activities beyond decommissioning (e.g. the provision of infrastructure for radioactive waste management or disposal). Such considerations were, however, beyond the scope of this preliminary assessment. In general terms, it should be noted that there may be a trade-off between maintaining a narrower, more precise focus on cost benchmarking with a more limited dataset (e.g. broadly comparable facilities and activities,

such as NPP decommissioning), versus having a broader focus, with a potentially larger dataset (e.g. decommissioning of a much wider range of nuclear facilities, or even enlarging the focus beyond decommissioning).

In this context, it should be noted that international cost benchmarking approaches are typically supported by a common cost-reporting structure. For NPP decommissioning, an internationally developed cost structure has already been developed and is presented in the *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (NEA, 2012). The ISDC was developed primarily as the international standardised structure to present costs for NPP decommissioning projects, but it would be suitable for use in the normalisation of data in the cost benchmarking context. Examples of experiences in the use of the ISDC in this way were presented, for example, in *Costs of Decommissioning Nuclear Power Plants* (NEA, 2016a), which also includes some principles and results of conversions from different cost estimation presentation formats into the ISDC. Although the ISDC was developed in a way that could be adapted to the decommissioning of other types of facilities, only the IAEA has done so at the international level for research reactors, in the context of the DACCORD programme (IAEA, 2017). To date, there are no international agreed cost structures for the decommissioning of other types of nuclear facilities, or for the provision of radioactive waste infrastructure.

Chapter 4 of this report identifies a large number of perceived barriers that may impede the implementation of benchmarking for NPP decommissioning. Other industries have demonstrated means to overcome such barriers, while providing models for international co-operation that could be used also for nuclear decommissioning.

The removal of these barriers to the implementation of benchmarking for NPP decommissioning will require co-ordinated efforts. Moreover, in order to be able to select and implement a particular option, it will be necessary to analyse potential barriers in more detail than was possible in this preliminary review. In particular it should be noted that competition law aspects are not considered in detail as part of this preliminary assessment.

5.2. Options for benchmarking for NPP decommissioning

Among the alternatives considered in this preliminary review of cost benchmarking, and bearing in mind the preliminary nature of this assessment and the caveats identified above, Option F appears to offer the greatest added value for NPP decommissioning. This option is characterised in the report as having a "rich functionality with facilitated member group collection/sharing arrangement". The summary profile for Option F is presented in Table 5.1 as "green" (where green = positive), because of the extent to which the option is expected to remove the barriers to benchmarking described in the report. To implement this option, a distinct organisation would likely need to be set up, or an existing organisation designated, to create and support a centralised database for project data. This organisation would supervise inputs and outputs, ensuring that aspects such as requirements for anonymisation and normalisation of the data are respected. Pursuing Option F would thus involve significant efforts, which would include the creation of an international approach incorporating nuclear regulators, authorities, operators and the supply chain, as well as co-operation in sharing cost and schedule data, and making use of relevant outputs to meet the particular needs of individual stakeholders.

Table 5.1: **Summary profile for Option F** (extract from Table 4.10)

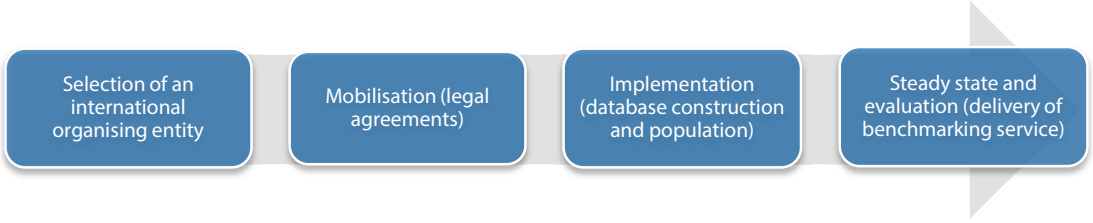
Option F: Rich functionality with facilitated member group collection/sharing arrangement + normalisation								
Managed collection, sharing and benchmark service	Supports removal of the headline industry barriers to cost benchmarking?					Satisfies added value being sought?	Relative order of cost	Rating
	Absence of actual cost data	Obstacles to normalisation	Low maturity	No incentive for industry engagement	No investment in organisation/ facilitation			
	G	G	G	G	G	G	High	A

Commentary: Potential benefit in aligned stakeholder groups. Stakeholders trust in third party data sharing and normalisation.

5.3. A possible roadmap for the implementation of benchmarking

A series of co-ordinated steps or a roadmap would be required to implement cost benchmarking at the international level in the manner described, for example, in the case of Option F. The series of steps is illustrated in general terms in Figure 5.1 below.

Figure 5.1: **Benchmarking implementation roadmap**



Step 1 – Selection of an international organising entity

A critical mass of stakeholders would need to be interested in participating in such an entity, for example a group of operators and national authorities with significant data, willing to share this data across international borders. Furthermore, this group would also need to select or create a distinct organising entity to oversee the initiative. Given the international nature of the envisaged collaboration, the primary options would likely be co-operation through some form of international organisation, or in the private sector. Examples exist of both types of organisational approaches, and a choice of a particular organisational model would require a more in-depth analysis.

Step 2 – Mobilisation

A legal agreement would need to be established outlining the participating entities, their relationship with each other and their relationship with the organisation selected or created for the benchmarking service. This agreement would identify the duties and obligations of the parties, the services they would receive in turn for participation, and any exit strategy, for example in the case that a restructure occurs, a participant leaves, or the benchmarking service is discontinued. The agreement would also address the requirements for additional entities joining the service after it has already been established.

Step 3 – Implementation

The cost benchmarking organisation would establish the database requirements and infrastructure, organise the services around input and output of data, and commence population with any available pre-existing data from participating members. The schedule for population would likely be driven by the availability of, and needs for, particular data, as well as comparisons by participating entities. The service would begin to be useful even before all data categories were fully populated.

Step 4 – Steady state and evaluation

Participating entities would regularly review the implementation, evaluate usage and the usefulness of the services, while continuing to refine and develop the service.

The sort of international co-operation envisaged for Option F would likely take a number of years to establish.

5.4. Moving forward

The relatively large number of NPPs internationally, as well as the considerable costs and long time frames envisaged in NPP decommissioning, suggest that benchmarking approaches for decommissioning costs deserves much greater attention. Other industries have led the way in demonstrating how cost benchmarking can provide valuable insights for managing costs and improving project delivery. Implementing such a service for NPP decommissioning, or for decommissioning more generally, will require international collaboration across the industry. The recommendations outlined in this report offer a way forward to proceed with a more detailed discussion and evaluation of options to develop and implement cost benchmarking for the decommissioning of nuclear power plants.

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Appendix A. Sweden case study: Interface with project delivery tools

Introduction

The different stakeholders described in Chapter 2 all have a need for follow-up on project performance such as cost and schedule. Thus, benchmarking in the context of decommissioning costs also plays an important role of added value in the interface with project delivery tools. Even if the level of detail in information needed by various stakeholder groups may differ, as described in Chapter 2, it is considered important that the follow-up on project performance is made in a systematic and consistent way. Studying and implementation of lean management principles and standardisation approaches provides valuable contribution in this context, e.g. regarding development of relevant key performance indicators (KPIs).

Background

Within Uniper the nuclear power plants of Oskarshamn 1 and 2, and Barsebäck 1 and 2 are to be dismantled. The two programmes are aligned on portfolio level and supported by Uniper Project Performance Center (PPC).

The PPC strives for a holistic, site overarching optimisation of the Uniper nuclear decommissioning and dismantling (D&D) activities. This means:

- prepare and follow up overarching decisions for the D&D project portfolio, in order to set standards and achieve the overall optimum in quality and cost;
- performance tracking and support;
- support optimisation of D&D resources.

The decision making and formal accountability and authority of the licence holders OKG and Barsebäck Kraft AB (BKAB) stay intact and the licence holder's representatives are integrated in the PPC leadership team and different working groups.

According to the regulatory framework, it is the responsibility of the licence holder to estimate the costs for all measures that are needed to manage and dispose of spent nuclear fuel, as well as other radioactive residual products from nuclear activities, and to decommission and dismantle the nuclear power plants.

Historically, decommissioning cost estimates are based on technical decommissioning studies performed by, respectively, TLG Services for Barsebäck and Westinghouse for Oskarshamn. These cost estimates are the basis for calculating fees and financial guarantees required in accordance with the regulatory framework and the Swedish financing system for financing decommissioning and radioactive waste disposal (i.e. the state Nuclear Waste Fund).

Since entering decommissioning, these rather theoretical studies and estimates are to be verified in the further project planning (e.g. budgetary offers). This is currently work being undertaken as part of the ongoing strategy development process. Therefore the following should be seen as a preliminary description.

Governance model

To customise project delivery tools for decommissioning, forming a relevant governance model is crucial. The basis for the governance model is the three major tasks in nuclear D&D; operation and maintenance; D&D work packages; and waste management.

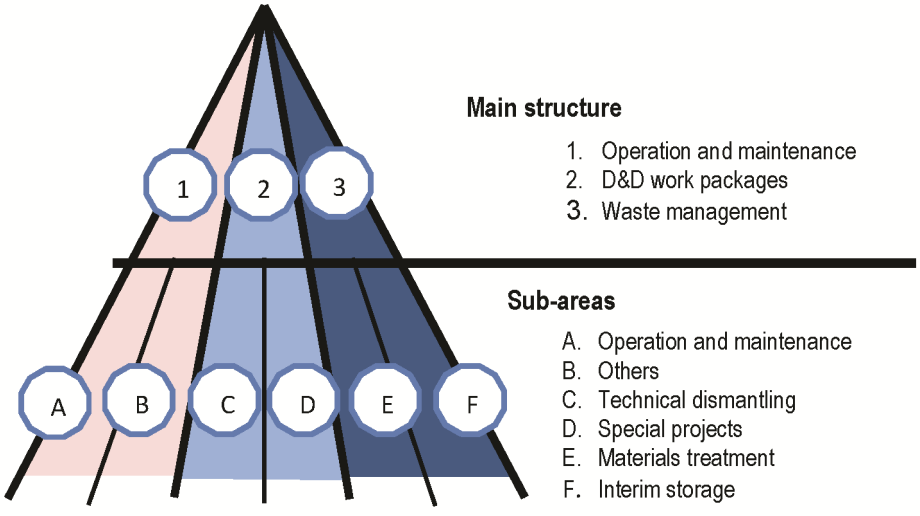
The measures for dismantling a nuclear power plant have a direct impact on waste treatment and on operation, maintenance and security (OMS). Dismantling of radioactive material is mostly manual work, where the number of required personnel is related to the planned performance and to the planned execution time. Transport and logistics, the need for infrastructure systems, and all expenditures are connected to the number of personnel in controlled areas and material handling. Fast D&D will need high capacity for waste treatment and thus increase the basic cost for OMS additionally.

Dismantling and decontamination require auxiliary functions like venting, waste water treatment, lifting devices, elevators for personnel, pressured air, etc. Usually, operational systems are used until these are to be decommissioned. Before decommissioning of these systems compensatory measures are required to fulfil the function until free release of building.

Nuclear responsibility requires a line organisation on-site, and safety and supervisory functions. The required resources correspond with the volume of activities on-site, but cannot be reduced below a minimum connected to legal required functions and responsibilities.

Understanding the overall tasks for nuclear D&D and the interfaces between them forms a simplified governance model described in Figure A.1 below.

Figure A.1: **Simplified description of governance model adapted for nuclear D&D**



Project delivery tools

At this point the decommissioning studies and their cost estimates form the reference documents for the monitoring and financial control of project delivery and available funds; however, as mentioned above the structure for this is under review as part of the strategy process.

The interface with project delivery tools in context of decommissioning cost estimations is considered to consist of planning of the decommissioning projects (i.e. refining understanding of the cost consequences of decisions) and execution of decommissioning projects (i.e. project controls and project delivery management).

The interface with project delivery tools for planning and execution of the decommissioning projects is structured on the basis of the three major tasks of nuclear D&D and suitable key performance indicators and the costs specifically related to them:

Operation and maintenance of auxiliary systems, surveillance of plant and plant security

These measures are necessary as long as the plant is a nuclear site and the radioactivity is not removed, to support D&D work and waste management. OMS expenditures are influenced by the decommissioning strategy. These base cost are directly connected to the ownership of the plant and to "time".

Use is made of the same principles as followed during the operation of a nuclear power plant and the project controls are comparable to the normal operation performance process.

Main key performance indicators (KPI) can be:

- availability of critical systems;
- specific cost for operation and maintenance;
- personal indicator (e.g. number of FTE);
- safety indicator.

D&D work packages

The decommissioning of systems and the "Dismantling" of radioactive material is required to fulfil the legal requirements of an operator. The measures can be somewhat delayed to the future, stretched or compressed. In general, the measures follow the principles of projects, even if they are directly influencing each other and operation mentioned above.

D&D work packages and special projects (e.g. treatment facilities, interim storage and system adaptions) follow the control and performance approach of a "major asset project".

Main KPIs can be:

- time (e.g. milestone trend analysis, schedule);
- cost;
- performance (e.g. dismantled mass [Kg], decontaminated surface [m^2]);
- resources;
- risk;
- safety indicator.

Waste management

The radioactive material has to be conditioned as radioactive waste or to be approved as not radioactive and released as not radioactive. Therefore the material has to be segmented, decontaminated, measured or packed as radioactive waste for interim and final storage.

Waste management requires control and performance principles of a production plant. The material from dismantling is comparable to "raw material" treated in different facilities and the qualified waste package and the material for free release are comparable to "products".

Waste management is steered "reactive" on the needs of dismantling, comparable to a "Single item production" reacting on customer's needs. Waste management is not "allowed" to become a "bottle neck" (adaption of capacity needed).

Main KPIs can be:

- inventory development, inventory control [number of boxes per storage; raw material inventory];
- facility specific performance and specific treatment cost;
- production performance [production input; production output; principle: all in= all out] and process failure indicator/error rate;
- risk;
- safety indicator.

Ongoing work and other interdependencies

Applying best practice for "major asset project" in nuclear decommissioning includes applying LEAN principles and implementing standardisation approaches. This includes adaptions of project delivery tools and forms an important task of the strategy development process. The strategy development process also includes risk management with direct interdependencies to both cost estimates and project delivery tools.

There are also more interdependencies than just between the cost estimates and the planning and execution of the project that needs to be addressed for the project delivery tools, for example in the context of financial reporting in relation to the Swedish Nuclear Waste Fund. Preliminary discussions have been held between the Swedish nuclear industry and the Swedish Radiation Safety Authority on how information developed in this context can be handled. However, no decisions have been made.

Appendix B.1. Details of barriers and enablers identified by industry

	Further Barriers (Disincentive to Engagement)	Potential (Provisional) Enablers to Remove the Further Barriers
Commercial Sensitivities	There is reluctance to share data because of risk to commercial advantage	Anonymization; Independent Custodianship;
	A policy of confidentiality prevents data sharing	Removal of barrier influenced by emergent approach
	Cost data is Intellectual Property attracting a premium or preventing release (sharing)	Removal of barrier influenced by emergent approach
	Procurement/Ownership of data/database impacts ability of Public Authorities to engage	Independent ownership; Transparent competitive procurement of managed BM service
Data Availability	There is a shortage of actual cost data (NPP and other)	Phased approach to development of BM maturity
	The cost data cannot be acquired from the owners	Removal of barrier influenced by emergent approach
	The cost data cannot be anonymised	Use of suitable proxies; Independent Custodianship;
	There is an industry reluctance to share data	Removal of barrier influenced by emergent approach
Data Integrity/Reliability	The quality of the cost data is unknown or undefined	Independent validation and characterisation
	The data is not independent	Independent validation and characterisation
	The data accuracy (range) is undefined	Independent validation and characterisation
	The data is incomplete, i.e. does not confirm that all costs are captured	Independent validation and characterisation
	The data is not reliable/accurate	Independent validation and characterisation
	The data is not characterised, i.e. what it represents is not validated and verified	Independent validation and characterisation
	The performance represented by the cost data is undefined, e.g. upper/lower quartile	Independent validation and characterisation
	The quality and character of the end-state/output/outcome delivered is not defined	Independent validation and characterisation
	The procurement approach adopted is not defined	Independent validation and characterisation
	What the cost represents commercially is undefined, i.e. price/cost/profit/preliminaries	Independent validation and characterisation
	The data is inconsistent in what it represents (scope and performance)	Independent validation and characterisation
Data Relevance/Usability	Normalisation cannot be achieved - boundary conditions cannot be satisfied	Normalisation: Capture of context and boundary conditions becomes a condition of participation
	The date line of the cost is undefined	Independent validation and characterisation - maintenance of data alignment with inflation/other change
	The definition of scope not represented clearly enough to make it useful	Regularise e.g. common WBS or Reporting structure e.g. ISDC
	Estimated cost benchmarks are made available present a risk to helpful data	Screen out estimated costs
Economic	The cost of data collection and analysis does not release commensurate benefits	Phased removal - To counter this, confidence needs to be developed from maturity of approach and data
	There is insufficient demand for data and benchmarking; collection/sharing is not a viable	Phased removal - To counter this, confidence needs to be developed from maturity of approach and data
	The investment required to establish data collection/sharing and BM is not available	Phased removal - To counter this, confidence needs to be developed from maturity of approach and data
Legislative	Legislation prevents the disclosure of cost and performance data outside hosts jurisdiction	Subject to the outcome of this report
	Legal barriers to sharing of information	Subject to the outcome of this report
Political and Geographic	The currencies cannot be resolved	Independent validation and characterisation - maintenance of currency alignment
	Lack of cross-geography comparability of strategy/approach prevents use of data	Capture of context and boundary conditions becomes a condition of participation - normalisation process
	The data is not perceived as trustworthy	Phased removal - To counter this, confidence needs to be developed from maturity of approach and data
Regulatory	State or national regulation prevents data disclosure and sharing	Subject to conclusion of this project
	Regulatory impact on cost cannot be recognised/normalised across regulatory boundaries	Subject to conclusion of this project
	There are differences in interpretation/standardisation of metrics, e.g. £/cu.m v $/sq.ft	Capture of context and boundary conditions becomes a condition of participation - normalisation process
Security	Data relates to secure installations/facilities and cannot be released.	Accepted
	The data and contributors are compromised by security breach	Secure custody and management of data and access; anonymization
Other	There is no common understanding nor transparent method of benchmarking	Subject to the outcome of this report
	There is no incentive for stakeholders to engage and participate	NEA Membership assent and influence; influence of emergent approach and business case
	There is no incentive for stakeholders to capture data in a usable (value-adding) form	NEA Membership assent and influence; influence of emergent approach and business case
	The cost of interpreting data (making it useable) outweighs benefits; approach is not viable	Subject to the outcome of this report
	There is no maturity in benchmarking in this sector discouraging engagement	Subject to the outcome of this report
	The approach is seen as one size fits all, discouraging niche/smaller stakeholders	Subject to the outcome of this report
	Schedule and other data associated with driving cost is not available/shared/defined	Subject to the outcome of this report
	The data and benchmarking is not available when needed	Subject to the outcome of this report
	Stakeholder buy-in is not secured for the data and approach	Subject to the outcome of this report
	The data and approach are not a fit with the stakeholder demand, e.g. strategic, PM	Subject to the outcome of this report
	There is no quick-fix; time to development of maturity and value discourages participation	Subject to the outcome of this report

Appendix B.2. Barriers and enablers: Approach to ascertaining interest group perspectives

This appendix describes an approach to further inquiry of stakeholder opinions on barrier removal. It sets out a framework within which to conduct further work to determine interest group definition, identification and approach to engagement.

This sort of assessment is envisaged during Step 2, "Mobilisation", of the roadmap described in Chapter 5. Accordingly, this step would include identification of the audience of interest groups for NPP decommissioning cost benchmarking and gaining their perspectives on the removal of the barriers to benchmarking. There is also an aim to understand stakeholder perspectives on the options for cost benchmarking, including the collection and sharing of data.

Interest groups – Definition and identification

The potential interest sits in groups planning for and conducting decommissioning. These might also have knowledge from already completed decommissioning projects. They will include executive decision makers, owners, operators, funders, regulators, and other entities accountable for cost estimation and delivery of decommissioning.

The interest groups that are most likely to create the critical mass referred to in Chapter 4, are those with the greatest potential to benefit from cost benchmarking. This critical mass needs to come together as a starting point or first stage of enabling barrier removal.

The interest groups will extend to those engaged in planning for new-build facilities, and those planning or authorising the funding for NPP decommissioning. Each group is likely to include roles with responsibility for strategic decision making, project cost estimation and project delivery management. Interest groups will include commercial providers of cost estimation and benchmarking services. Other interested parties include the independent institutions and commercial associations representing the interests of the industry and its participants. In summary, there is a large audience of potential stakeholders, each with differing specific interests but together forming a significant collective interest in developing a workable approach that adds value.

The interest groups seeking value from cost benchmarking, can have different areas of focus, and are therefore likely to have a different perspective on the enablers:

- Executive decision makers, who for example, might use whole-project benchmarking to challenge cost estimate ranges with regard to the stage of maturity of the subject or target project;
- Project delivery management teams, including cost estimators, who might use activity-level benchmarking to challenge and/or build cost estimates.

The benchmarking interests of each are not mutually exclusive. While this is a convenient way of categorising the two fundamental approaches considered by this project, the interest groups that they sit in, will generally be able to gain value from both approaches. It is therefore helpful to start identification of the interest groups from the market perspective.

Beneficiaries and consumers of benchmarking

Chapter 4 suggests that removal of some principal barriers to benchmarking is necessary to remove the many other barriers that are thought to contribute to them. The enablers for removal of the principal barriers are interdependent, and so must be addressed together. Implementation of these enablers, for the options that materially add value (Options C to F presented in Chapter 4), will demand significant co-operation, collaboration, investment and organisation before the value of the benchmarking it aims to produce can be demonstrated.

It will therefore be necessary to build a shared understanding of the potential benefits of benchmarking to those in the industry who will potentially stand to realise the greatest value from it. It is these parties who are most likely to be prepared to co-operate, and invest in the start-up and development of benchmarking, and in developing maturity over a significant period. They will therefore have the greatest influence over the successful implementation of the option(s) selected to deliver benchmarking.

Others who might be included in a "long-list" (provisional list) are regulatory authorities and the principal supply chain actors.

Suppliers of data

In addition to the potential beneficiaries and consumers, other interest groups will include those organisations and stakeholders who have the ownership and knowledge of actual cost data produced by completed, ongoing and near-term projects (the suppliers of data).

There are many possible stakeholders in this area, who might gain most (as beneficiaries and consumers) from the value offered by benchmarking, and/or offer most in terms of data collection and sharing. There remain numerous stakeholders even if focus is narrowed to completed decommissioning projects, and those currently being undertaken or planned. To these might be added those organisations who are responsible for planning and authorising funded decommissioning plans as part of new-build projects.

These parties will include those most likely to support, co-operate and invest in the start-up and development of benchmarking, and in developing maturity over a significant period. From this long-list, identification of a more manageable short-list is required to inform the selected approach and strategy for advancing benchmarking.

Some potential interest groups are likely to be on both the supply and demand side (data providers and benchmarking consumers), and as such, there is a risk they choose to remain independent from any collaboration. These groups might prefer to protect their commercial position and not engage. While the industry would benefit by collectively agreeing to invest in and "trigger" the development of benchmarking, there is a risk that gaining buy-in to collaborate might be difficult for some owners of data.

Benchmarking service suppliers

The providers of cost benchmarking services currently include many cost estimating consultancies and analysts. These operate across a range of industries, including for example, mainstream construction and engineering, infrastructure, utilities, energy and resources. Many are global multidisciplinary practitioners with experience of benchmarking at project level, and also benchmarking at the activity level, which includes the development of data and databases for cost estimating.

Some of the options presented in Chapter 4 require the use of such service providers. These are an interest group in terms of acting as potential suppliers of benchmarking services.

Interest groups – Engaging these groups in a benchmarking approach

This section examines the engagement of interest groups in taking forward benchmarking, and creating the "critical mass", or level of audience participation that is needed to move forward the preferred option to deliver benchmarking.

Engaging the audience for benchmarking

An audience that is sufficient for moving forward selected option(s) for benchmarking, i.e. a "critical mass", is likely to comprise:

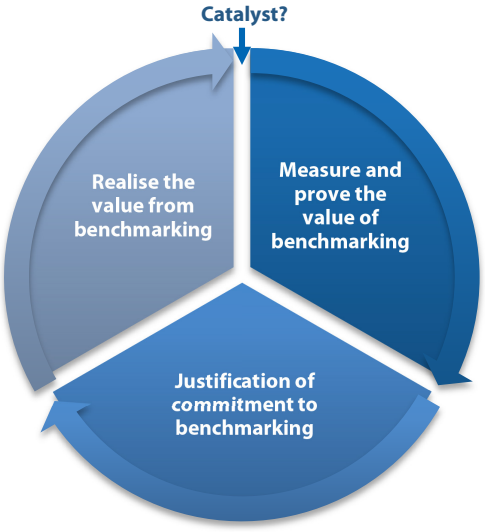
- multiple geographies (though not necessarily all);
- multiple operators;
- elements of regulatory bodies and authorities;
- elements of the supply chain.

To proceed will require that a sufficient part of industry engages, supports, co-operates and invests in the enablers removing the headline barriers to benchmarking. It is likely that this is represented by those with the greatest demand for NPP decommissioning, represented by those with the greatest number of reactors for which the IAEA PRIS provides information.

To achieve this, it is likely that each interest group will require a satisfactory business case, which justifies the investment to receive the value or benefits. In other words, each interest group will need to be able to justify the engagement, and reconcile the investment needed, in terms of the value (benefit) that it will receive.

Measuring and demonstrating to potential participants the clear value from benchmarking options requires some commitment and speculative investment from those same prospective participants. This is because the value available cannot be demonstrated by hard examples from within the industry, until such time that benchmarking matures. It also requires that both the data and the organisation that support it are established. This is a high hurdle and potential barrier to progressing benchmarking.

Figure B2.1: **The need for a catalyst to justify industry buy-in to commit to benchmarking?**



While options in the form of enablers have been identified to remove this barrier, the need for commitment to implement the enablers, requires a bringing together of participants with strongest interest and influence. This is likely to require independent facilitation by an institution to engender support in the membership. However, the key enabler remains the willingness of the "critical mass" of potential participants to commit and invest in the delivery of value. This requires an informed "leap of faith", which at this starting point for benchmarking within this industry, can only really be justified by reference to relatively little industry evidence or evidence from elsewhere. This means evidence of value attained by other industries, about which the nuclear decommissioning industry might be sceptical, both in terms of comparability and the value delivered.

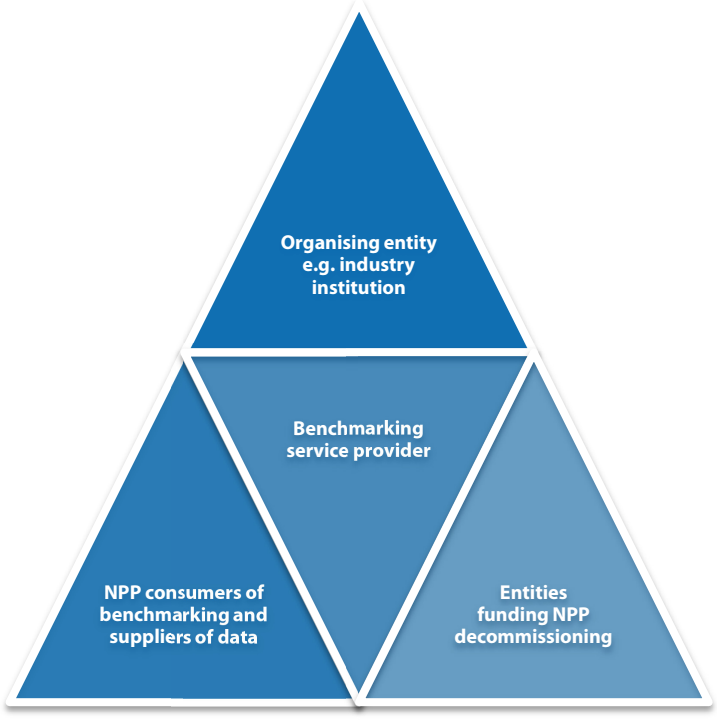
This is a significant risk to the advancement of benchmarking, which the project concludes will require:

- the leadership of, and intervention by an institution with global influence over the potential participants;
- the ultimate buy-in of the potential participants or "critical mass".

The critical mass for benchmarking

What constitutes the critical mass in any particular case, will be dependent upon the option(s) that are developed and taken forward. To achieve removal of the barriers for NPP decommissioning benchmarking, it is likely that the core components illustrated below will be present.

Figure B2.2: **Enabling components to form the critical mass necessary for removal of headline barriers**



Appendix B.3. Enabling benchmarking option analysis

The tables contained in this appendix provide some additional details for each of the options A-F presented in Table 4.10 in Chapter 4. As noted earlier, all of these options will also need to be assessed under competition law, as this issue was not considered in detail as part of this preliminary assessment. It should be noted also that, for all these options, the removal of the initial barriers to benchmarking is assumed.

Option A: Enabling benchmarking – "do nothing"

Description	Benefits (added value)	Relative costs ($, $$, $$$) and disbenefits	Risks
• The problem remains unaddressed – situation carries on as at present • The industry does not collaborate in the external collection and sharing of data, nor in the development of a benchmarking approach • Internal benchmarking continues and ad hoc commercial or alliance driven benchmarking might emerge over time as knowledge accumulates	• Stakeholders (executive decision makers/authorities and regulators) collect their own actual cost data and share it internally only. The structure and contextualisation of the data is internal to the organisation, but might be a recognised global breakdown structure • No/low investment • Sensitivities protected	**Relative cost: N/A** **Disbenefits:** • The value sought by the industry is not delivered • Decision making and cost estimating does not benefit and industry does not learn from the actual cost information available • Isolated (not industry-wide) benefit; no external benchmarking; value and benefits from external practice and performance are not realised. Incentive is that sensitivities are protected, but no contribution to removal of industry headline barriers to benchmarking	**There is a risk that:** • Disparate approaches arise from those at the forefront of decommissioning and dismantling, leading to silos of data that cannot be contextualised for the benefit of others • Internal benchmarking builds in additional risk, e.g. fostering poor practice and inefficiency – if the only internal benchmarks available are for projects with poor outcomes, then there is a low bar set for new projects

Commentary: Isolated (not industry-wide) benefit, low investment; no external benchmarking; added value and benefits from external practice and performance are not realised. Incentive is that sensitivities are protected but no contribution to removal of industry headline barriers to benchmarking.

Option B: Raw data/isolated data collection and sharing

Description	Benefits (added value)	Relative costs ($, $$, $$$) and disbenefits	Risks
• Stakeholders (executive decision makers/authorities and regulators) collect and share direct with each other "raw" cost information, without contextualisation, i.e. the knowledge and confidence elements of actual cost data are lacking • Sharing is bilateral, or multilateral within peer groups informally or under an alliance agreement or Memorandum of Understanding	• The value sought by the industry is not achieved • Isolated benefit, low investment; might deliver value within group with closely aligned facility/project types and context • Potential for sensitivities to be protected by agreement providing some incentive, but no significant contribution to removal of industry headline barriers to benchmarking	**Relative cost: $ (low)** **Disbenefits:** • Decision making and cost estimating does not benefit and industry does not learn from the actual cost information available • Isolated (not industry-wide) benefit; no external benchmarking; added value and benefits from external practice and performance are not realised • Incentive is that sensitivities are protected but no contribution to removal of industry headline barriers to benchmarking	**There is a risk that:** • Disparate approaches arise from those at the forefront of decommissioning and dismantling, leading to silos of data that cannot be contextualised for the benefit of others • The external "raw" cost information carries significant risk without the knowledge and confidence added to the cost information

Commentary: Isolated benefit, low investment; the external "raw" cost information carries significant risk without the knowledge and confidence added to the cost information; might deliver value within group with closely aligned facility/project types and context. Potential for sensitivities to be protected by agreement providing some incentive, but no significant contribution to removal of industry headline barriers to benchmarking.

Option C: Contextualised data/peer group collection/sharing arrangement

Description	Benefits (added value)	Relative costs ($, $$, $$$) and disbenefits	Risks
• Stakeholders (executive decision makers/authorities and regulators) collect and share directly with each other under a common agreed governance (structure, process and procedure) the actual cost data, i.e. with knowledge and confidence elements contextualised and structured to a commonly agreed cost breakdown or reporting structure • Data input is made directly to a database; sharing is by accessing the database between or within peer groups or an alliance under an agreement • There is no validation of data contributed, and normalisation and benchmarking are undertaken by the stakeholder organisations themselves	• Moderate benefit; the external actual cost data might deliver value within group with closely aligned facility/project types and context • Potential for sensitivities to be protected by agreement, but contribution to removal of industry headline barriers to benchmarking, and usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so is in demand by participants	**Relative cost: $$ (medium)** **Disbenefits:** • Small users might find it difficult to engage where they have little to offer the other stakeholders, e.g. where they have no actual and relevant cost data to contribute, and only a small demand for benchmarking	**There is a risk that:** • Only the larger organisations will invest • Likely participation is limited to group of stakeholders recognising their common challenge (type, approach and context) • The removal of headline barriers, which are a dependency for this approach, cannot be achieved

Commentary: Moderate benefit and investment; the external actual cost data might deliver value within a stakeholder group with closely aligned facility/project types and context. Potential for sensitivities to be protected by agreement, but contribution to removal of industry headline barriers to benchmarking and, usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so is in demand by participants. Likely that participation is limited to group of stakeholders recognising their common challenge (type, approach and context).

Option D: **Facilitated member group data collection/sharing arrangement – no normalisation**

Description	Benefits (added value)	Relative costs ($, $$, $$$) and disbenefits	Risks
• Stakeholders (executive decision makers/authorities and regulators) collect and share direct actual cost data through a forum, which they sponsor and subscribe as members • The forum and data collection and sharing is managed by an independent party under a common agreed governance structure, processes and procedures • The actual cost data, i.e. with knowledge and confidence elements contextualised by the suppliers of data, is structured to the agreed cost breakdown or reporting structure • Data input is undertaken by the facilitator to the agreed database and the data is anonymised; sharing is by accessing the facilitator database • There is no independent validation of data contributed, and normalisation and benchmarking are undertaken within the stakeholder or third party organisations	• Moderate benefit; the external actual cost data might deliver value within group with closely aligned facility/project types and context • Potential for sensitivities to be protected by agreement, but contribution to removal of industry headline barriers to benchmarking, and usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so is in demand by participants	**Relative cost: $$ (medium)** **Disbenefits:** • Small users might find it difficult to engage where they have little to offer the other stakeholders, e.g. where they have no actual and relevant cost data to contribute, and only a small demand for benchmarking	**There is a risk that:** • Only the larger organisations will invest • Likely participation is limited to group of stakeholders recognising their common challenge (type, approach and context) • The removal of headline barriers which are a dependency for this approach cannot be achieved

Commentary: Moderate benefit and investment; the external actual cost data might deliver value within group with closely aligned facility/project types and context. Potential for sensitivities to be protected by agreement, with some contribution to removal of industry headline barriers to benchmarking, and usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so is in demand by participants. Likely that establishment and participation is slow in developing until value and success can be demonstrated, limited to a group of stakeholders recognising their common challenge (type, approach and context), and prepared to make investment required to kick-start and make delivery viable for a commercial operator.

Option E: Facilitated industry collection and sharing arrangement – data published with no normalisation

Description	Benefits (added value)	Costs ($, $$, $$$) and disbenefits	Risks
• Stakeholders (executive decision makers/authorities and regulators) sponsor and subscribe under an independent industry institution (e.g. not for profit), the development of an industry database • The forum and data collection and sharing, is conducted and managed by an independent party to the institution that is the facilities delivery to a common agreed governance (structure, process and procedure) • The actual cost data, i.e. with knowledge and confidence elements contextualised by the suppliers of data, validated by the institution/facilitator, and structured to the agreed cost breakdown or reporting structure by the facilitator • Data input is undertaken by the facilitator to the agreed database which is an appropriately accredited model suitably assured and the data is anonymised. Sharing is by publication by the custodian institution • Normalisation and benchmarking is by the stakeholder	• Potential significant benefit requiring significant investment; the external actual cost data might deliver value within the industry with closely aligned facility/project types and context • Potential for sensitivities to be protected by agreement, with contribution to removal of industry headline barriers to benchmarking dependent on demonstrable added value; usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so fits to the demand by participants • Likely that there is little incentive to contribute data and that the investment required to contextualise it discourages participation • Establishment and participation are likely to be slow to develop until value and success can be demonstrated; limited to a group of stakeholders recognising their common challenge (type, approach, context), and prepared to make the significant investment required to kick-start and make delivery viable for a commercial operator	**Relative cost: $$$ (high)** **Disbenefits:** • Small users might find it difficult to engage where they have little to offer the other stakeholders, e.g. where they have no actual and relevant cost data to contribute, and only a small demand for benchmarking	**There is a risk that:** • Only the larger organisations will invest • The removal of headline barriers which are a dependency for this approach cannot be achieved • Likely participation is limited to group of stakeholders recognising their common challenge (type, approach and context)

Commentary: Potential significant benefit requiring significant investment; the external actual cost data might deliver value within the industry with closely aligned facility/project types and context. Potential for sensitivities to be protected by agreement, with contribution to removal of industry headline barriers to benchmarking dependent on demonstrable added value; usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so fits to the demand by participants. Likely that there is little incentive to contribute data and that the investment required to contextualise it discourages participation. Establishment and participation is likely to be slow in developing until value and success can be demonstrated; limited to a group of stakeholders recognising their common challenge (type, approach and context), and prepared to make the significant investment required to kick-start and make delivery viable for a commercial operator.

Option F: **Rich functionality with facilitated member group collection/sharing arrangement and normalisation**

Description	Benefits (added value)	Costs ($, $$, $$$ etc.) and disbenefits	Risks
• Stakeholders (executive decision makers/authorities and regulators) collect and share direct actual cost data through a forum which they sponsor and subscribe as members • The forum and data collection and sharing, is conducted and managed by an independent party to a common agreed governance structure, processes and procedures • The actual cost data, is validated by the institution/facilitator, and structured to the agreed cost breakdown or reporting structure by the facilitator • Data input is undertaken by the facilitator to the agreed database which is an appropriately accredited model suitably assured and the data is anonymised; sharing is by accessing the facilitator services • The facilitator offers a menu of benchmarking services including, for example, normalisation, benchmarking, project review (e.g. at approval stage), project performance review, industry insight and support. The performance of the facilitator is monitored and assured by the stakeholders	• Potential significant benefit requiring significant investment; the external actual cost data might deliver value within group with closely aligned facility/project types and context • Potential for sensitivities to be protected by legal agreement, with contribution to removal of industry headline barriers to benchmarking dependent on demonstrable added value; usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so fits to the demand by participants • Likely that establishment and participation is slow in developing until value and success can be demonstrated; limited to a group of stakeholders recognising their common challenge (type, approach, context), and prepared to make the significant investment required to kick-start and make delivery viable for a commercial operator	**Relative cost: $$$ (high)** **Disbenefits:** • Small users might find it difficult to engage where they have little to offer the other stakeholders, e.g. where they have no actual and relevant cost data to contribute, and only a small demand for benchmarking	**There is a risk that:** • Only the larger organisations will invest • Likely participation is limited to group of stakeholders recognising their common challenge (type, approach and context) • The removal of headline barriers which are a dependency for this approach cannot be achieved

Commentary: Potential significant benefit requiring significant investment; the external actual cost data might deliver value within group with closely aligned facility/project types and context. Potential for sensitivities to be protected by agreement, with contribution to removal of industry headline barriers to benchmarking dependent on demonstrable added value; usefulness of data shared is dependent on extent and scale of stakeholder buy-in, and that the actual cost data collected adds value and so fits to the demand by participants. Likely that establishment and participation is slow in developing until value and success can be demonstrated; limited to a group of stakeholders recognising their common challenge (type, approach and context), and prepared to make the significant investment required to kick-start and make delivery viable for a commercial operator.

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Cost Benchmarking for Nuclear Power Plant Decommissioning

The nuclear sector has in recent years been placing increasing attention on the need to better understand variations between cost estimates for the decommissioning of nuclear power plants, as well as the relationship between estimated and actual costs, and the apparent escalation of these costs. Building on previous work by the Nuclear Energy Agency, *Cost Benchmarking for Nuclear Power Plant Decommissioning* examines approaches and methods for the benchmarking of nuclear power plant decommissioning costs. Particular focus is given to identifying key factors, drivers and constraints to implementing cost benchmarking. These factors are addressed from a broad range of perspectives in order to develop a roadmap for implementation that will garner sufficiently broad support from a wide base of interested stakeholders. The report also identifies a number of perceived barriers that may impede the implementation of benchmarking for decommissioning. Co-ordinated efforts and further analysis will be needed to help remove these barriers.

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