Radioactive Waste Management
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# Financing the Decommissioning of Nuclear Facilities

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Radioactive Waste Management

# Financing the Decommissioning of Nuclear Facilities


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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

## ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes;

- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.



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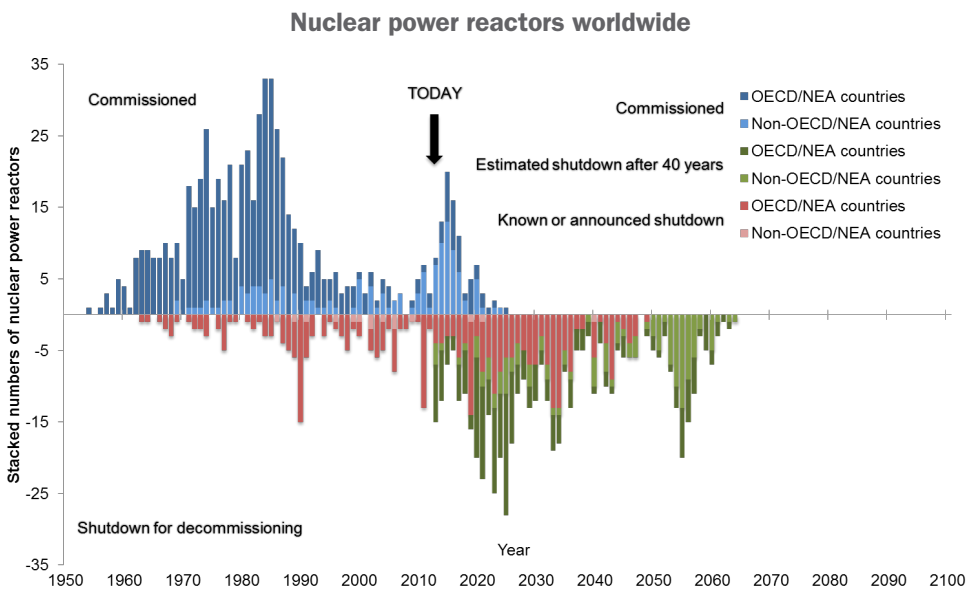
# Context*

As commercial nuclear power continues into its sixth decade, a growing number of nuclear reactors are at or reaching the decommissioning phase. Since the beginning of the commercial nuclear industry, as of July 2016, 157 civilian nuclear power reactors had ceased operation in 19 countries, including 33 in the United States, 30 in the United Kingdom, 28 in Germany, 12 in France, 16 in Japan, 6 in Canada and 5 in Russia (IAEA, 2016). These 157 reactors include mostly commercial power reactors, but also prototypes (~30) and experimental reactors (~15), either shut down at the end of their life as originally envisaged in the design, or prematurely closed as a result of financial, political or other considerations (NEA, 2016).




* This document was originally prepared by Inge Weber, Nuclear Decommissioning Specialist in the NEA Division of Radiological Protection and Radioactive Waste Management, as a background note for the April 2016 policy debate of the NEA Steering Committee for Nuclear Energy.

A total of 446 nuclear reactors are in operation around the world, providing about 11% of global electricity and the second largest low-carbon source of energy globally after hydroelectric power. However, the average age of the operational nuclear fleet is close to 30 years. Nearly 250 reactors are more than 30 years old, and some 75 are over 40 years old. Another 66 nuclear reactors are currently under construction, mainly in Asia and in non-NEA member countries.

There are two opposing trends which may impact the timing of when reactors are closed and enter into the decommissioning phase. In recent years, refurbishments for long-term operation and operating licence extensions have become more common, with many licences granted for nuclear power plant operation up to 60 years in some countries, notably in the United States (NEA, 2016). However, it is unclear whether all such life-extension plans will be pursued to completion and/or be successful. Moreover, changes to political (e.g. Germany) or economic conditions (e.g. Sweden, United States) may impact the operating periods of reactors.

There is a sound technical basis existing for the execution of decommissioning work (i.e. issues around decommissioning have largely been resolved from a technical point of view). Several commercial and research facilities have been fully decommissioned, but recent experience with completed decommissioning projects and thus data on decommissioning costs for current plants is limited. Therefore, decommissioning financing still relies primarily on cost estimates rather than actual decommissioning cost data, and it is not clear how well current decommissioning cost estimates reflect actual decommissioning costs in many countries.

In 2012, the NEA published the *International Structure for Decommissioning Costing* (ISDC) to provide an improved basis for preparing comprehensive and comparable decommissioning cost estimates internationally. A variety of financing mechanisms are in place to cover the costs of nuclear reactor decommissioning, but the adequacy and robustness of these mechanisms are largely untested because of the limited number of completed nuclear power reactor decommissioning projects.

# Overview of decommissioning financing

A characteristic feature of policies and strategies for the decommissioning of nuclear facilities is the relatively long time horizons involved. Thus, today's generations have to make – and are already making – decisions with consequences reaching out to future generations. In order to be sustainable, these decisions should be based on ethical considerations, be possible to implement and take into account a wide range of uncertainties. The purpose of this report is to offer a brief overview of relevant considerations on decommissioning financing with a focus on processes, responsibilities and uncertainties.

Key considerations in terms of sustainability are as follows:

- The health and safety of current and future generations is the primary concern of decommissioning and decommissioning funding.
- The generations using nuclear power facilities have an obligation to assemble and to preserve the financial, technical and scientific resources necessary for the later decommissioning of these facilities. The generally acknowledged "polluter pays principle", stating that those causing pollution should meet the clean-up and other costs to which it gives rise, should be applied when funding the costs of decommissioning nuclear facilities.
- A principle of intergenerational continuity (a chain of responsibilities whereby the present generation must transfer resources and reasonable obligations to the succeeding generation) should also apply (NEA, 2006) and thus must ensure that funding for the costs of decommissioning nuclear power facilities should be guided by the principle of avoiding imposition of undue burdens on future generations.

Ultimately, the availability of adequate funds for decommissioning is linked to the safety and protection of current and future generations (NEA, 2006). Sound financial provisions should be built up in good time to ensure that all decommissioning costs are covered and to reduce the potential risks of residual unfunded liabilities and burden on future generations, while ensuring environmental protection.

Existing systems and practices for funding the decommissioning of nuclear power facilities incorporate the "polluter pays principle" with the aim of not imposing undue burden on future generations (while taking into account the needs of present societies). When formulating principles for funding and sharing the costs of decommissioning, concepts such as equity and justice are indispensable,

and need to be qualified and defined in more depth before being used in the formulation of ethically sound principles.

Decommissioning programmes are long-term activities that are crucially dependent on the availability of waste management and disposal pathways. Delays in the availability of final disposal pathways may cause significant additional costs to be covered by the operator's decommissioning funds. In some countries, agreements on shared funding to cover these additional costs of decommissioning resulting from such delays are put in place to reduce undue burden on the operators.

Likewise, in some systems, an earlier than expected permanent shutdown of a nuclear facility, sometimes referred to as "premature shutdown", may interrupt contributions to decommissioning funds before the liabilities are fully financed. Furthermore, the failure of a fund to reach a sufficient level of financing to cover the full costs of decommissioning may mean the need to draw on financing from other sources.

Currently, key considerations from the outset include identification of the provision of funds for the decommissioning project as well as requirements for financial assurance concerning the adequacy and timely availability of resources for safe decommissioning (IAEA, 2014). In most NEA member countries, mechanisms for providing decommissioning funding are in place and based in national law or regulation. However, they differ in the way that the funds are accumulated, the oversight and even in the scope of funding according to different national legislation and practices. Because financing programmes are based in many different regulatory and legal systems, there is not an international standard or universal best approach to ensuring the availability of decommissioning funds.

Legal and/or regulatory frameworks are required and have been put into place in most countries for the creation of decommissioning funds. These frameworks also guarantee that the funds will not be diverted for other purposes. Such measures are needed to ensure:

- Contributions to the funds are made by facilities using radioactive material during their operation so that sufficient funds are available at the time of final shutdown in order to cover necessary decommissioning and waste management expenses.
- Contributions are in line with the estimated service life, defined time schedule and chosen strategy, as laid down in the decommissioning plan in order to cover decommissioning of the facility.
- The funds are managed and reviewed periodically in a manner that allows sufficient liquidities compatible with the timetable for the decommissioning obligations and their costs.
- The funds are used only to cover the costs of the decommissioning obligations in line with the decommissioning strategy.
- Legal and administrative remedies are available and enforceable in the event of non-compliance with the above points (NEA, 2016).

## Decommissioning cost estimation

For any nuclear facility, adequate financial resources need to be secured to cover the costs of decommissioning as well as spent fuel and radioactive waste management, including disposal. The amount of funding needed is based on the establishment of a decommissioning plan estimating the decommissioning costs, and a waste management plan estimating the associated waste management costs on-site and off-site (including waste disposal). For nuclear reactors, spent fuel management costs must be considered unless they are a part of the operational costs. In addition, these cost estimates should take into account the analysis of associated risk and uncertainties.

The activities that the decommissioning funding needs to cover typically begin with the permanent shutdown of the nuclear facility and end at the earliest with the planned end state (e.g. a cleared facility following the full clean-up of the site, with removal of radioactive materials and structures from the facility site) (NEA, 2015a). However, early decommissioning planning and preparation activities usually start three to five years before the final shutdown of a facility and should be taken into account.

The decommissioning plan for a nuclear facility establishes the basis of any estimation of decommissioning costs. Specific requirements on the contents of the decommissioning plan and the frequency of the updating of the cost studies are usually set out in regulations, which have their basis in national legislation. Practices for estimating decommissioning costs vary across countries and projects, and efforts are being made to improve cost comparability (NEA, 2012a) and reviewability of cost studies (NEA, 2014), and to consolidate the practice and process of decommissioning cost estimation (NEA, 2015b).

Decommissioning cost studies are produced for many purposes, mainly for securing funding, in the context of the decommissioning licensing process and for the budgeting of a baseline for decommissioning implementation. They are produced and updated at different stages of a nuclear facility's life cycle. It is now common practice to prepare decommissioning plans and associated cost estimates for nuclear facilities even during the plant design stage, before construction starts, in order to enable designers and client organisations to establish overall project costs and to inform the long-term financing process to provide for future funds when the facility will be decommissioned (NEA, 2015b).

The following elements have been found to drive costs in the actual decommissioning of nuclear facilities that have not undergone a major accident (NEA, 2013a and 2015b):

- the decommissioning strategy, i.e. the scope of work through to the end state of the site;
- assumed duration of the dismantling and clean-up activities;
- regulatory requirements, including details of reporting and clearance levels;
- stakeholders' demands;
- characterisation of the physical, radiological and hazardous materials inventory;
- waste processing, storage and the availability of final disposal facilities;
- obligations associated with management of spent nuclear fuel, including on-site storage before its disposition;
- clean structure disposition and making the site available for new developments;
- contingency application and use in the estimates;
- availability of experienced personnel with knowledge of the plant.

The most important considerations in ensuring stable decommissioning cost estimates include: avoiding changes in project scope (for example the decommissioning strategy and the end state of the site), fixing regulatory standards during the decommissioning planning phase to avoid delays during active decommissioning, early development and availability of a national radioactive waste infrastructure and accurate characterisation of materials and soil.

Using a project management approach for decommissioning planning and performance inevitably places emphasis on the use of cost and schedule control software and management tools that ultimately help to avoid decommissioning project budget and schedule overruns (NEA, 2013a).

## Review of decommissioning cost estimations

Regularly reviewing cost estimates, including their underlying decommissioning plans, and comparing them with the actual cost of decommissioning activities ensures the quality of these estimates (NEA, 2013a). Decommissioning cost studies are requested to be conducted or updated periodically by the facility operator or other assigned organisations. Both the frequency and the review mechanism vary considerably from country to country. They are reviewed by the utility or a decommissioning entity, by the national nuclear regulator, by both the utility/decommissioning entity and the government or nuclear regulator, or in some cases by administrative bodies for the fund (NEA, 2016).

Some reviews also require a cost-benefit analysis, or the equivalent, for assessing alternative decommissioning technologies and techniques (NEA, 2013a).

There is no internationally accepted decommissioning cost standard, and even within one country with several nuclear facility owners, different methodologies for calculating cost estimates can be found. Thus, the supervisory body must give consideration to how it will assess the presented calculations. This might require national regulators to *i)* require nationwide use of a single cost estimate methodology (for the European Union, probably the *International Structure for Decommissioning Costing* [ISDC]) and *ii)* have capacities for assessment of such cost estimates (NEA, 2015a).

## Benchmarking decommissioning costs

Cost figures should not be taken at face value and be compared unless all boundary conditions, assumptions and other details and key factors (such as the attitude towards risk and uncertainty) of the cost study are made clear (NEA, 2012a and 2015b). Since there is no internationally accepted decommissioning cost standard, only a range of values (often cited between EUR 0.5 and 1 billion for the decommissioning of a single-unit nuclear power plant for example) can generally be given for the costs of decommissioning projects, not median or average cost values. In a recent NEA study on costs of decommissioning (NEA, 2016), the estimated costs of decommissioning a nuclear power plant in Europe ranged between EUR 0.5 and 1.6 billion. But these estimates are also highly dependent upon a range of factors such as the methodologies used, the national context, the regulatory framework and the costs of waste management.

It is advisable to benchmark the costs of specific activities rather than entire projects. It must be further considered that the cost of decommissioning projects will vary with the number of facilities or units on the same site and with the degree of experience from previous decommissioning activities. These factors will affect the efficiency of processes or alternative strategies. Overall, these normal cost variations make it challenging to compare entire project costs across projects and countries.

## Costs of financing

The specific amounts to be collected to cover the costs of decommissioning are influenced not only by the estimate of the decommissioning liability (decommissioning cost estimate), but also by the investment strategy and expected rates of return on investment of fund assets (costs of financing) (NEA, 2016).

# Decommissioning funding

The financing of decommissioning is in most countries ensured through the establishment of a fund, preferably segregated from the accounts of the licensee/owners (operators) of the nuclear facility. In general, the scope of funding, the funding mechanisms and oversight differ considerably from country to country. For example, in some countries one fund is intended to cover both the financing of the costs of decommissioning, as well as waste and spent fuel management up to disposal; in others, separate funds are raised to cover the decommissioning and dismantling costs including associated waste management costs on-site. Whichever arrangements are made, both liabilities must cover different time frames implying specific economic and financial management considerations.

In some cases there may be a need to make special decommissioning funding arrangements for so-called "legacy" facilities that are no longer in operation and for which insufficient provisions were made for future decommissioning during their operation. In addition, some countries also have separate financing arrangements for government-funded facilities. In such cases, there may be more than one decommissioning funding system in operation at the same time in a particular country.

## Collection of decommissioning funding

The way decommissioning funds are accumulated varies from country to country. In general, in the case of a nuclear power plant, funds for decommissioning are set aside from the revenue obtained from the sale of electricity generated by the plant during its operating phase, or through a levy on sales of electricity of any origin. A levy may also be applied to the net profits that the operator may make from other goods and services provided (NEA, 2006). In some cases, for nuclear power plants with multiple units, the collection of funds may be organised on a site-wide basis or, if the owner has several sites, it may be pursued on a fleet basis.

The common mechanisms for raising funds to cover the costs of decommissioning nuclear power plants are charges included in the electricity price, compulsory government charges and other approaches or a combination of several approaches. Thus far, taxes have not been raised to fund decommissioning (NEA, 2016).

## Timeline for building up the funds

In most cases the fund is built up year by year, either over the entire expected lifetime of the facility or over a shorter period, and is based on the calculated decommissioning cost estimate. The funds may be collected over a shorter period or through prepayments to reduce the risk associated with unplanned, premature shutdown. In all cases, these mechanisms are intended to balance the need for affordability with the need to reduce risks associated with the possible premature shutdown of a facility or unfunded decommissioning liabilities.

The adequacy of the financing arrangements and financial resources in comparison to the assessed liability is periodically reviewed. Exact frequency of reviews varies from country to country, ranging from annually to every six years, or only when and if it is required, but with the tendency to be conducted according to the same frequency and mechanisms as the reviews of the decommissioning cost estimates. There is also no standard for the reviewing mechanism and responsibilities (NEA, 2015a and 2016).

## Management of decommissioning funds

Any management strategy of decommissioning funds should aim to match the full decommissioning cost and to ensure its availability at the time when it is needed, under the control of the national body (EU, 2013). Ensuring the adequacy of the funds is a top priority, and planners must account for uncertainties such as the fluctuations of the stock and bond markets and the long-term development of the global economy. Different management strategies are adopted in different countries, with fund ownership or control by the government, utility/operator, other bodies or even without specific requirements for the control over decommissioning funds.

In some countries, the licensee/owners (operators) are allowed to accumulate and manage their own decommissioning funds that remain in their own accounts. In this type of approach, referred to as **internal management of the funds or accruals**, the operators have full responsibility for the respective investment and any potential losses, for which they would have to compensate (NEA, 2006). In other countries, the funds are collected from operators or via the electricity market system, and are managed by separate, independent bodies. Through this approach, referred to as **external management or trusts**, the organisation responsible for the funds needs to manage and control the assets in such a way to ensure that the fund at least retains its value and is not disbursed on anything other than its identified purpose. In the case of external management, compensation for any losses may need to be addressed in the legal and regulatory framework (NEA, 2006), in addition to measures necessary to address the risk of fund loss due, for example, to bankruptcy of the owner of the facility or a downturn in financial markets.

In some countries there are specific features relating to the access or use of the decommissioning funds that may not be directly related to actual decommissioning. For example, facility operators contributing to the fund are entitled to borrow back a percentage of the capital of the fund, against provision of full securities and at a defined, government-fixed rate. In addition to such arrangements, in some countries the state may have the right to borrow the capital of the fund (IAEA, 2005).

## Control and oversight of funds

All fund management models face a common challenge, namely the risk of not being sufficient or not being available for the decommissioning obligations and for covering their costs, owing, for instance, to premature shutdown, escalation of costs, underperformance of funds, financial difficulties or bankruptcy of the operating company, or resulting from a change of ownership. Economic stability is necessary for a sound, long-term funding system (NEA, 2016).

Decommissioning liabilities themselves can be volatile, with increases or decreases in the cost of decommissioning, since variations in costs are sensitive *inter alia* to changes in regulations, waste disposal policy, politics and plant conditions as the nuclear facility ages. All these underlying assumptions can be a source of risks.

Furthermore, the payment stream should be responsive to changes in the general economy and fund performance. In addition to having adequate financial resources and disbursements restricted to pre-identified objectives, nuclear decommissioning funds should be designed to allow sufficient flexibility such that sufficient financial resources are available to cover all relevant activities in an approved decommissioning plan at the time such resources are needed. The liabilities that remain following the closure of a nuclear facility should be managed safely, even though this could be over a period that ranges from a few years to possibly more than 100 years. The future implementation of the decommissioning project, depending on the strategy chosen, will require specific timetables for decommissioning liabilities and for related disbursements. It is crucial that the financial resources for the safe management of these costs can be guaranteed over the full period and in a manner ensuring liquidities compatible with the timetable for the decommissioning obligations and their costs.

The management of funds should be transparent to the respective national authorities and other relevant stakeholders as regards the accumulation of money, the expenses and the financial management. National legislative and regulatory frameworks have established rigorous rules to control the access to decommissioning funds and the timing as to when they can be withdrawn (IAEA, 2005). Spending limits and release of the funds could be tied to specific milestones of the project, in which case there could be a required documented evidence to support authorisation of expenditure. There are a variety of national systems in place for reviewing the financing and operation of the funds. While

the details vary considerably between countries, in all cases these arrangements constitute a system of checks and evaluations, with a differentiation of powers and responsibilities from those more closely related to the operational issues, where oversight is typically of a more technical, expert nature, to policy considerations, where there is typically a role for a state authority or government.

In circumstances causing insufficiency or unavailability of decommissioning funds, missing financial resources must be covered by other sources. There is a variety of different protective measures and strategies applied in NEA countries to mitigate relevant risks associated with the funding mechanism, responsibilities for the funding as well as with the fund performance (financial risks such as inflation and escalation risks, market risks, credit risks, currency risks and administrative risks) (NEA, 2016).

## NEA activities in the field of decommissioning

The NEA has many activities underway in the field of decommissioning. The **Working Party on Decommissioning and Dismantling (WPDD)** serves the Radioactive Waste Management Committee (RWMC) and the NEA to increase outreach and efficiency in the field of decommissioning. The WPDD provides a forum for the analysis of decommissioning policy, strategy and regulation, including the related issues of management of materials, release of buildings and sites from regulatory control and associated cost estimation and funding. Beyond policy and strategy considerations, the WPDD also reviews practical considerations for implementation such as techniques for the characterisation of materials, decontamination and dismantling.

The **WPDD Decommissioning Cost Estimation Group (DCEG)** was created to foster the exchange of information and experience on issues in this field. In promoting collective learning on the subject, it aims to enhance the credibility, reliability and auditability of the cost estimation process, thereby enhancing stakeholder confidence in the process of managing radioactive waste management liabilities. The group helps define best practices in the field of decommissioning cost estimation and to examine the scope for achieving consensus on overall objectives and developing common approaches. The current focus of this group is on uncertainties in decommissioning cost estimation.

The **WPDD Task Group on Radiological Characterisation and Decommissioning (TG-RCD)** seeks to identify and describe important issues and risks related to strategies for waste and materials management processes for the optimised final disposition of waste and materials. The main objective is to develop a status report on the selection and tailoring of strategies for the optimisation of nuclear facility characterisation from a waste and materials end-state perspective.

The **WPDD Task Group on Nuclear Site Restoration (TGNSR)** focused on strategic considerations for sustainable nuclear site clean-up of subsurface contamination during decommissioning as summarised in the report *Strategic Considerations for the Sustainable Remediation of Nuclear Installations*. It provides insights for the decision makers, regulators, implementers and stakeholders involved in nuclear site decommissioning to ensure the sustainable remediation of nuclear sites, now and in the future. The developed strategic approach describes how the long timescales involved in remediation can be addressed. It also helps in decision making on site end states and interim states.

The **WPDD Task Group on Preparing for Decommissioning during Operation and after Final Shutdown (TGPFD)** was established to identify and help define best practice in the field of preparing for decommissioning. Observations and recommendations will be summarised in a status report to be considered in the development and optimisation of strategies and plans for preparing the decommissioning of nuclear facilities in the last years of operation and after final shutdown to achieve value added, safety of workers and improvements in project management consistent with best practice, which enable the timely delivery of decommissioning targets.

The WPDD and its subsidiary bodies also **provide expert input to other NEA activities related to decommissioning**. In co-operation with the RWMC and the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC), the WPDD and the DCEG supported the update of a 2003 study to review nuclear power plant decommissioning costs and funding practices adopted across NEA member countries. The principal objectives of this study were to gather and assess the available knowledge on completed decommissioning projects; to review economic methodologies and related aspects for the management of nuclear power plant decommissioning, including the funding mechanisms; to perform a review of related cost estimates; and to define, to the extent possible, cost categories and estimates for high-level processes with the aim of identifying cost ranges. The study, entitled *Costs of Decommissioning Nuclear Power Plants*, was published in 2016.

Furthermore, the RWMC and the NDC are planning to co-operate on a future project on structure, adequacy and financing of funding arrangements for decommissioning, spent nuclear fuel storage and disposal in NEA member countries.

The **International Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD)** is a joint undertaking that was established in 1985 under Article 5 of the NEA Statute. Initially consisting of 10 decommissioning projects in 8 countries, the programme has since grown to 68 projects (39 reactors and 29 fuel cycle facilities) from 26 organisations in 14 NEA member countries, 1 non-OECD member economy and the European Commission. Decommissioning projects have benefited from the information exchange framework provided by the CPD. The information exchange includes biannual meetings of the Technical Advisory Group (TAG), during which the site of one of the participating projects is visited, and where positive and less positive examples of decommissioning experience are openly exchanged for the benefit of all. The forum offered by the programme is valuable in ensuring that the safest, most economical and environmentally friendly options for decommissioning are employed.

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# Financing the Decommissioning of Nuclear Facilities

Decommissioning of both commercial and R&D nuclear facilities is expected to increase significantly in the coming years, and the largest of such industrial decommissioning projects could command considerable budgets. It is important to understand the costs of decommissioning projects in order to develop realistic cost estimates as early as possible based on preliminary decommissioning plans, but also to develop funding mechanisms to ensure that future decommissioning expenses can be adequately covered. Sound financial provisions need to be accumulated early on to reduce the potential risk for residual, unfunded liabilities and the burden on future generations, while ensuring environmental protection.

Decommissioning planning can be subject to considerable uncertainties, particularly in relation to potential changes in financial markets, in energy policies or in the conditions and requirements for decommissioning individual nuclear installations, and such uncertainties need to be reflected in regularly updated cost estimates.

This booklet offers a useful overview of the relevant aspects of financing the decommissioning of nuclear facilities. It provides information on cost estimation for decommissioning, as well as details about funding mechanisms and the management of funds based on current practice in NEA member countries.

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