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NUCLEAR ENERGY AGENCY

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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, as well as

- 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 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. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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Foreword

The NEA Decommissioning Cost Estimation Group (DCEG), in collaboration with the IAEA Waste Technology Section and the EC Directorate-General for Energy and Transport, has recently studied cost estimation practices in 12 countries – Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Slovakia, Spain, Sweden, the United Kingdom and the United States. Its findings are to be published in an OECD/NEA report entitled *Cost Estimation for Decommissioning: An International Overview of Cost Elements, Estimation Practices and Reporting Requirements*. This booklet highlights the findings contained in the full report.

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It is now common practice for decommissioning plans and associated cost estimates to be prepared for all nuclear installations. Specific requirements are generally set out in regulations which have their basis in national legislation. These estimates are important for ensuring that the necessary funds are being collected to cover the actual costs of decommissioning the facility. The long time horizon for both amassing and disbursing these funds is a particular concern for national authorities, as a balance needs to be struck between the duty of the current generation to set aside sufficient funds in secure, low-risk investments and its right not to have to set aside excessive provisions for future costs, thus resulting in resources being unduly removed from productive uses.

During the last decade, national authorities in several countries have begun to take a keener interest in estimates of national waste management and decommissioning liabilities and in the adequacy of the provisions made to discharge them over time. Decommissioning cost and schedule estimates are thus an essential prerequisite for ensuring that adequate funds will be available when a nuclear facility is ultimately shut down. Regulators and affected publics look to the owner/licensees to provide an accurate, reliable estimate upon which to establish the necessary financial provisions in an equitable and justifiable manner.

Currently, the format, content and practice of cost estimation vary considerably both within and between countries, which makes it very difficult to compare estimates, even for similar types of facilities. The reasons are largely due to different legal requirements in different countries and to historical custom and practice, leading to variations in basic assumptions such as the anticipated decommissioning strategy and end state of the site, and to different approaches to dealing with uncertainties. While attaining harmonisation across national approaches to cost estimation may be difficult to achieve, standardising the way decommissioning cost estimates are structured and reported would give greater transparency to the decommissioning process and would help build regulator and stakeholder confidence in the cost estimates and schedules.

The Decommissioning Cost Estimation Group (DCEG) of the Nuclear Energy Agency, in close collaboration with the Waste Technology Section of the International Atomic Energy Agency (IAEA) and with the Directorate-General for Energy and Transport of the European Commission, is currently working on an update to the OECD/NEA, IAEA and EC report *Nuclear Decommissioning: A Proposed*

Standardised List of Items for Costing Purposes (1999), with the aim of providing a standard reporting template onto which national cost estimates can be mapped for the purposes of national standardisation and international comparison.

Roles and responsibilities of interested parties

In most countries, owners/licensees are responsible for developing decommissioning plans, cost estimates and funding mechanisms. They are required to prepare or update them periodically and to submit them for approval to a designated competent authority – the nuclear safety regulator or a financial administrator. This usually occurs on a 3- to 5-year time frame or following significant changes in decommissioning-related factors. In some countries a cost-benefit analysis must be undertaken to justify the selection of a particular decommissioning strategy. The competent authority also reviews the funding mechanism used to ensure adequate funding for decommissioning. Most national authorities do not prescribe a reporting format but reference studies are generally available for guidance.

Decommissioning plans are no longer simply the affair of the institutions closely involved in decommissioning. In recent years affected publics have been increasingly encouraged to review decommissioning plans and, in some cases, cost estimates and funding arrangements. Those responsible for decommissioning may also engage affected publics in developing a vision and plans for the site end state. The consultative process may be facilitated through a local information commission or community oversight board, which may comment on technical issues and influence the direction being taken for the decommissioning of the facility. Alongside these civil society representatives, environmental planners and site developers should be considered as stakeholders, as post-decommissioning redevelopment of the site can have a significant impact on the decommissioning strategy and costs. Increasingly, institutional plans are not approved until stakeholder comments and concerns have been addressed satisfactorily.

Reuse of a former nuclear installation as a mechanical test workshop.

Former research reactor RB-2, near Bologna, Italy.
[Photo: IAEA Report TRS 444 (2006)]

Requirements regarding costs to be included

Decommissioning may encompass several broad cost categories related to a) decontamination, dismantling and termination of the licence of facilities, and b) the management of spent fuel and wastes, including legacy wastes from plant operation, waste transportation, storage and disposal. Which of these costs should be included in a decommissioning cost estimate is governed by the legal and administrative framework that defines the scope of decommissioning under the relevant regulatory scheme. In some countries, long-term storage/disposal costs for spent fuel and/or radioactive waste management activities are included in decommissioning cost estimates, whereas other countries treat these costs separately for provisioning purposes and separate funding systems are in place. Hence, the structure, organisation and scope of the cost estimates largely depend on what is defined by national regulation as being within and outside of decommissioning.

Assumptions and boundary conditions

The types and level of detail of assumptions and boundary conditions typically applied in cost estimates have a major affect on the overall costs. Virtually all national regulations require operators to provide an explanation and justification of the assumptions used in estimating their costs. These include boundary assumptions and conditions such as the year of the estimate, end point/site release criteria, transition activities, characterisation, remote handling techniques, spent fuel management, processing and storage/disposal of high-level waste and/or spent fuel, processing and storage/disposal of residual operational and decommissioning wastes, scrap/salvage of materials and project management.

Former power plant site now ready for environmental conservation or economic redevelopment – a small portion of the site is used for the Independent Spent Fuel Storage Installation.

Former site of Maine Yankee nuclear power plant, USA. [Photo: Maine Yankee Atomic Power Company]

Cost reduction and characterisation

Several countries require consideration of cost-reduction possibilities. Countries having a comprehensive national decommissioning and waste disposal programme commonly emphasize the need to include in estimates costs associated with waste minimisation. The overall costs of decommissioning and waste management are largely determined by the radiological inventory and the extent of contamination, waste categorisation requirements and the degree of decontamination required, and the availability of waste management infrastructure. An important precondition for cost reduction is performing adequate characterisation of the site and of the material intended for disposal. Clearance and release levels also have a major impact on costs, as does the selected end state for the site – "greenfield" or "brownfield". These terms broadly distinguish cases where there are no restrictions on the future use of the site (greenfield) from those cases where some restrictions are placed on future usage (brownfield). The terms need to be defined in detail in the estimate, as there is currently no universal interpretation. In most countries, a greenfield end state of the site is anticipated for costing purposes; alternatively, it is foreseen that the site will be a "brownfield", i.e. reused for other industrial purposes or for building a new nuclear installation. Such redevelopment of decommissioned sites may generate cost savings due to less restrictive radiological release criteria, or to sale or reuse of site infrastructure and land. Generally, the use of proven technology also contributes to cost reduction.

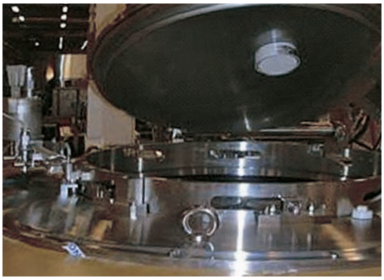
Handheld mechanical cutting equipment for small contaminated pipes, conduit and ducting. BR-3 decommissioning project, Mol, Belgium. [Photos: SCK•CEN]

Types of cost

Activity-dependent costs are those costs associated with performing hands-on decommissioning activities. Examples include decontamination, removal of equipment, and waste treatment, conditioning, transport, and storage or disposal. These activities lend themselves to the use of unit cost and work productivity factors (or work difficulty factors) applied to the plant equipment and building inventories to develop the decommissioning cost and schedule.

Period-dependent costs include those activities related to the project duration: engineering, project management, licensing, health and safety, security, energy and quality assurance. Project management staff costs are found by estimating the number of personnel required and associated overhead costs based on the scope of work to be accomplished during individual phases within each period of the project.

Certain items that do not fall into either of the above categories may be referred to as collateral costs, e.g. the cost of construction or dismantling equipment, site preparation, insurance, property taxes, permits, health physics supplies, liquid radioactive waste processing and independent verification surveys.



Mock-up of a uranium thorium solution solidification plant.

Itrec pilot scale research facility, Trisaia, Italy. [Photo: SOGIN]

Categories of cost drivers

Cost drivers and elements can be divided into four main categories:

1) Basic assumptions and definition of the project scope and boundaries:
   - year of the estimate and base costs without inflation;
   - start point for decommissioning and definition of physical boundaries of the project;
   - end state criteria and conditions for the facility and the site;
   - transition from operation to decommissioning, including facility/site characterisation and inventory;
   - ongoing operations not specific to active decommissioning.

2) Sources for unit cost for various activities, i.e. the origin of standard cost data needed to build up the estimate:
   - source of employee salary and craft labour rates;
   - source of material and equipment costs for conventional demolition of uncontaminated equipment and structures;
   - source of material and equipment costs for monitoring, radiological and hazardous materials decontamination, and dismantling of contaminated materials and buildings.

3) Assumptions for management of materials and waste to be generated from decommissioning:
   - management of decommissioning primary and secondary wastes (recycle, storage or disposal);
   - management of residual wastes from operations (including processing/conditioning of contaminated metals and recycling options);
   - availability of waste storage and disposal facilities;
   - waste container options (including shielding, capacity, design life and limitations on their use);
   - waste transportation options (truck, rail or barge), including weight or radioactivity limits on containers and casks;
   - high-level waste and spent nuclear fuel management (on-site or off-site storage or reprocessing);
   - cost savings from material scrap/salvage and site/facility reuse.

Disposal of very low-level radioactive waste.

El Cabril disposal facility, Spain.
[Photo: ENRESA]

4) Technical assumptions and definition of the planned decommissioning strategy:

- major component disposition (one-piece intact, or segmented);

Disposal of the reactor pressure vessel from the Trojan NPP.

Richland disposal facility for radioactive waste, Washington, USA.
[Photo: US Ecology, Inc.]

- scrap and salvage identification and disposal;
- construction of new facilities or modification of existing facilities to facilitate decommissioning;
- disposal of structures (reactor, auxiliary, turbine, diesel generator, fuel buildings);
- infrastructure disposal (cooling towers, intake and discharge structures, security buildings);
- strategies for procurement and overall project management (self-performance or contractor-managed);
- decontamination factors and yields associated with intervention techniques (full system flush versus manual methods);
- choice of technologies for remote handling;
- R&D of new or untested decontamination or dismantling techniques.

Segmenting large plant items during the dismantling of the cooling towers for residual heat removal.

Caorso nuclear power plant, Italy.
[Photo: SOGIN]

Category 1 cost drivers have generally the greatest influence on the estimated cost, given that they establish the boundary conditions for the estimate, and are important considerations when making comparisons between different cost estimates. It needs to be established at the outset whether spent fuel removal and storage or reprocessing, transition activities from operation to decommissioning, characterisation and inventory, operations for maintenance, surveillance and security (or segments of any or all of these) are to be included or not in the decommissioning cost estimate. Equally important is the end state of the site. The monetary assumptions (monetary units, inflation or cost escalation[1] and the discount rate) are also very important because they can change the results of the cost estimate without any variation in the technical and other basic assumptions.

Category 2 cost drivers are more technical but are less problematic because their effect on cost estimates can readily be taken into account.

Category 3 cost drivers are important due to the relative importance of waste management costs as a proportion of the total costs. These costs are closely linked to the Category 1 cost drivers because of the way management of wastes may be included in the first group (boundary assumptions). It is important to establish whether final waste disposal to a national repository or if only interim storage on site is to be included in the cost estimate, the unit cost for disposal, the kind of repository (geological or near-surface) and the clearance levels to release materials, all of which can have an significant effect on cost estimates.

Category 4 cost drivers represent the technical choices made by the owner with respect to decommissioning strategies and activities and represent the "core" of the cost estimate. In comparing cost estimates, and where the Category 1 and Category 3 cost drivers are the same (i.e. the scope of the estimate is not a comparative factor), this group represents the essential difference in the cost estimates. A corollary of this is that a prerequisite for a meaningful comparison of different cost estimates is a standardised approach to representing the Category 1 and Category 3 cost drivers.

1. This means escalation beyond normal price inflation (which is based on a consumer price index), and reflects changes in costs associated with enhanced regulatory environmental requirements, unanticipated waste disposal fees, extended on-site waste storage costs etc.

Ranking of key cost elements

Cost elements can typically be grouped as follows in terms of their significance as cost drivers in decommissioning cost estimates:

Very significant

- scope definition and changes to the project plan;
- regulatory changes and increased requirements for additional information and detail;
- end point state and disposal of wastes;
- site characterisation of physical, radiological and hazardous materials inventory;
- waste storage and the availability of ultimate disposal facilities;
- disposal of spent nuclear fuel and on-site storage prior to a permanent repository;
- future use of clean structures and of the site for new developments;
- contingency application and use in estimates to account for uncertain events;
- availability of experienced personnel and continuing access to their knowledge of the plant;
- assumed or calculated duration of the dismantling and clean-up activities.

Moderately significant

- year of the estimate;
- inflation;
- cost escalation;
- discount factor(s);
- waste containers;
- start point for decommissioning and boundary conditions;
- transition from operations to decommissioning;
- project management and organisation.

National cost estimation practices

A wide variety of approaches are applied to the development of cost estimates, depending on the primary objective, i.e. whether it is to provide a basis for funding or to proceed with preliminary studies before undertaking the work. Calculation methods vary by country, for example using "bottom-up" (activity-by-activity) techniques or "parametric" (comparative) techniques. Some countries specify the type of cost estimate expected from operators (e.g. by imposing a broad cost structure and boundary conditions), while others leave it to the operator to determine. The use of life cycle planning models is prevalent in some countries, with worst case scenarios being used to bound the costs. Some countries specify in detail how costs are to be reported, while others specify the major cost categories whilst allowing greater discretion on how estimates are structured.

Why cost estimates may be wrong

A sensitivity analysis of the most significant cost drivers provides a means of improving the adequacy of the estimates for planning and funding purposes. Information from decommissioning projects suggests that the aspects most likely to cause estimates to be wrong include:

- changes in scope of work and/or regulatory standards and associated design changes;
- changes in scope of work required to address stakeholder concerns;
- financial considerations and availability of funds;
- contingency costs;
- differences in cost estimation methodology;
- knowledge management;
- change in project boundaries over time (including assumptions about project duration);
- legacy material and waste;
- licence delay.

Contingencies and uncertainties

Contingencies are defined as unforeseeable elements of cost within the defined project scope, while uncertainties may also cover unforeseeable elements outside the defined project scope, or changes in the scope of the project as defined (such as currency exchange rate fluctuations, inflation beyond the norm of around 5% and regulatory changes). Various approaches are applied to the assessment of uncertainty, e.g. uncertainties within the defined project scope are generally included as contingencies within the cost estimate. These need to be differentiated from uncertainties outside the defined scope, which are typically addressed by ensuring that funding arrangements have adequate flexibility, e.g. by providing funding guarantees. Some countries use a defined contingency.

Risk management

Risk management, in terms of ensuring that sufficient funds are available to cover decommissioning expenses when they are due, falls more in the realm of financing rather than contingency estimates. Risk analyses are performed in some countries, based, for example, on Monte Carlo calculations – calculating a range of cost estimates and assigning simple distributions to each, followed by multiple iterations calculating the distributions in size of the liabilities. Some countries require that cost estimates provide for escalation whereas, in others, this is specifically excluded.

Reflections on good practices

- Important considerations in ensuring accurate cost estimates include: methodological accuracy and consistency (for example, recognising that year-to-year funding tends to cause cost overruns); avoiding changes in project scope (notably the decommissioning strategy and end point); good characterisation; consistent regulatory requirements; involvement of the plant operator; the approach to setting contingency levels and risk management. Current good practices also include the use of a standardised list of activities, a strong quality assurance programme, use of a dedicated decommissioning core group, and involvement of regulators and stakeholders in the planning of decommissioning.

- It is likely that more detailed cost models, and associated cost data, will need to be used as the project advances. Such models should be continuously updated using cost data from actual decommissioning projects, thus improving the cost assessment, providing better control of uncertainties and contingencies for each major cost category and facilitating the preparation of an annualised schedule of expenditures for each facility.

- Distinguishing costs according to different project phases can provide a basis for establishing financing requirements that better reflects overall uncertainties, with the possibility of applying different contingency factors to project time frames.

- Risk management may benefit from an approach that uses a deterministic calculation (base case) that feeds into a probabilistic assessment of future costs. Such approaches may be used to gain a better understanding of potential cost and programme implications of different future scenarios.

- Regulatory standards should be addressed and fixed in the early stages of planning to avoid delays during the active stages of decommissioning.

- Early attention should also be given to socioeconomic factors, including impacts caused by loss of employment, to help in building public support and acceptance of a decommissioning project. Early interactions with stakeholders may be used to agree elements such as project boundary conditions, strategy, release criteria and measurement protocols, and waste containers used.

- Consideration should be given to developing upgraded decommissioning management systems to deal with latest developments, data quality, completeness and safety, while offering flexibility in data processing and cost calculations. Regular interaction between the developers and users of such systems, including those involved in ongoing decommissioning projects, is necessary to develop their efficacy and user friendliness.

- In view of the very significant impacts that scope changes and scope growth may have on cost estimates, it is important that these be identified and analysed immediately and incorporated as soon as possible into the estimate so that the estimate may continue to provide a viable benchmarking resource.

Overall observation

Standardisation of the format and content of cost estimates will give greater transparency to the decommissioning process and build regulator and stakeholder confidence in the cost estimates and schedules. The NEA and the IAEA are working to facilitate this process.

Further information on cost estimation for decommissioning

Recent summary publications

- *Decommissioning Funding: Ethics, Implementation, Uncertainties*, OECD Nuclear Energy Agency (2006).
- "Financial Aspects of Decommissioning", IAEA-TECDOC-1476, International Atomic Energy Agency (2005).

International organisations

- NEA/RWMC Working Party on Decommissioning and Dismantling (WPDD) and the Co-operative Programme on Decommissioning (CPD):
  www.nea.fr/html/rwm/wpdd
  www.nea.fr/html/jointproj/decom.html
- IAEA:
  www.iaea.org/Publications/index.html
  www-newmdb.iaea.org/
- European Commission:
  http://europa.eu.int/comm/energy/nuclear/decommissioning/index_en.htm

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