Radioactive Waste Management
2014

Guide for International Peer Reviews of Decommissioning Cost Studies for Nuclear Facilities

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 31 countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, the Republic of Korea, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission also takes part in the work of the Agency.

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. 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

As older commercial and research reactors and fuel cycle facilities become redundant, the need for accurate cost estimates for decommissioning will increase. Since one of the OECD's core strengths is its ability to offer its members a framework to compare experiences and examine best practices in a host of areas, many member countries will turn to the OECD Nuclear Energy Agency (NEA) to organise peer reviews of decommissioning costs studies in order to determine the quality of the estimates for funding, for preparing decommissioning plans and for baseline estimates to be used for implementation.

Peer reviews are a standard co-operative working tool of the OECD, and the NEA has a proven methodology for conducting peer reviews in waste management and nuclear R&D. The present guide is intended as a starting point for the process of international peer reviews of decommissioning cost estimate studies. Under the aegis of the NEA, such peer reviews will help national programmes or relevant organisations assess and improve decommissioning cost estimate practices in the future.

The primary focus of this guide is on single-unit nuclear power plants, including both pressurised water reactors (PWRs) and boiling water reactors (BWRs). The approach is also applicable to multiple-unit sites and may be extended to any nuclear facility, provided the appropriate adjustments are made.

This guide uses a reference template to structure a qualitative review of cost estimates and makes extensive use of internationally developed checklists that are not intended to be prescriptive or limiting. The approach ensures a high level of consistency from one peer review to another. The guide is designed for the peer reviewer(s), but should also be shared with the peer reviewee prior to the peer review, and more generally with any applicants/owners/licensees and estimating consultants so as to provide guidance on what may be expected in terms of quality and confidence in the estimates and on relevant peer review questions.

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1. Introduction

1.1 Objective

The objective of this guide is to provide:

- orientation to peer reviewers in preparation for the peer review;
- a process to review the cost estimate study with respect to its content and the underpinning support for the estimate results;
- any applicants/owners/licensees and estimating consultants and future reviewee(s) with guidance as to what may be expected in terms of quality and confidence in the estimates and relevant peer review questions.

1.2 Scope

By providing checklists for each attribute of a quality cost estimate, this guide is designed to establish a process for international peer reviews of decommissioning cost studies.

The primary focus of the guide is on single-unit nuclear power plants, including both pressurised water reactors (PWRs) and boiling water reactors (BWRs). The approach is also applicable to multiple-unit sites and it may be extended to any nuclear facility, including research reactors, fuel fabrication facilities, reprocessing plants and accelerators, provided appropriate adjustments are made for the physical and radiological differences and process modifications.

This report was prepared on the basis of long-term costing experience and is not directly based on the ISDC [1]. In principle, any items presented in this report may have an ISDC interpretation. It is recommended that users of this report allocate accepted ISDC identification numbers and interpretations when developing their own checklists for peer reviews.

1.3 International peer reviews under the aegis of the NEA

Peer reviews are a working method – a standard practice – that is closely associated with the OECD Nuclear Energy Agency (NEA) where it is seen as an instrument for both co-operation and change. The NEA performs country reviews on a regular basis and in a host of areas. The peer review process and outcomes are means of increasing, and demonstrating maturity and accountability. Peer reviews raise confidence in the ability of an organisation/country to implement best international practices (complemented by the quality of NEA databases, analyses and projections). Peer reviews – if used as a tool by a majority of organisations/countries – are a way to apply and consolidate international practice. The peer review will also benefit the organisations assisting reviewers and the ensemble of the member countries.

Peer reviews are themselves part of best practice. NEA co-ordinated peer reviews are organised on request by governments and based on agreed terms of reference (ToR). The reviews are performed by independent reviewers who take responsibility for their views, and the examination is carried out on a non-adversarial basis.

Overall, the NEA, as a forum for co-operation, helps to provide a framework for peer reviews to take place, without performing or sanctioning the peer review itself.

1.4 Organisation of this report

The remainder of this guide is divided into eight chapters. Chapter 2 describes gathering the cost estimate study and underpinning documents, reviewing the study and writing a final report. Chapter 3 provides a detailed checklist approach for the review of the cost study report. Chapter 4 provides checklists to assist in reviewing benchmarked information. Chapter 5 provides comments on the approach and recommendations for use of this guide. Chapters 6 and 7 provide the background material used in developing this guide and Chapter 8 provides a list of the abbreviations and acronyms used in this guide.

2. Conducting international peer reviews

An NEA co-ordinated peer review can be described as a systematic examination and assessment of a national programme or a specific aspect of it, with the ultimate goal of helping the requesting country – and its relevant organisations – to comply with established principles, adopt best practices and, at times, improve policy.

The review of a cost study report, the questions and answers (Q&A), and the lessons learnt are shared among the NEA member countries, contributing to an elevation of the working standards beyond the reviewed country. Until now NEA-organised peer reviews have had a technical focus, even if they had important policy consequences.

Peer reviews are never the end-goal but a tool in a process of continuous development. While there is value in the review report, much benefit is received from the process of undergoing the peer review itself.

Accountability, willingness to learn from experience and opportunities to develop improved practices are all important aspects of peer reviews. Peer reviews are also an insight into the way organisations constitute and manage internal teams in preparing for decommissioning.

Having well-established peer review procedures helps bring in and reinforce international culture among member countries. A well-established process also limits the variability that would arise from having different peer review teams.

For a complete list of the concepts that have been used in this report, the reader is further advised to consult *The Practice of Cost Estimation for Decommissioning Nuclear Facilities* (NEA, forthcoming) [2], which is a companion report to the present report.

2.1 Practical aspects

The review will be based on agreed upon terms of reference (ToR) that are negotiated between the NEA and reference contacts in the NEA member country. The ToR establishes the scope of the peer review and also explains what to avoid.

The NEA will assemble the international review team (IRT), and the names of team members will be communicated in due course to the reviewee so as to check that the conditions concerning conflict of interest are fulfilled. The members of the team will all be foreign nationals, representing a broad range of affiliations and geographical origins. They will be free from any conflict of interest. Reviewers are typically – but not exclusively – elicited and selected from experts participating in

NEA activities. Criteria for peer review team qualifications are described in Appendix A.

Although the "front team" may consist of only a few people (e.g. four to eight persons), typically other colleagues from the home organisation support their front team member. There is a very good return on investment as much more work is performed and input received than by simply looking at budgets or at the number of reviews.

Observers from other NEA member institutions may be allowed to participate in the IRT, for learning purposes or to support an official member of the team. This creates additional opportunities for learning and improving best practice internationally.

The process of review will take a few months from start to finish depending on availability of requested information and the response time from the reviewee. Funding is provided to the NEA to cover the costs of organising the peer review, including use of staff resources at the Secretariat.

The administrative process for requesting and for conducting international peer reviews under the aegis of the NEA is also described in the *International Peer Reviews of Radioactive Waste Management* (NEA, 2005) [3]. In the next sections of the guide we give further guidance on the process of peer review in the field of decommissioning cost studies.

2.2 The review process

There are several stages or steps in the review process, which need to take into consideration the timing necessary to allow the reviewers and the reviewee to gather the requested information and the underpinning to support the cost estimate study.

2.2.1 Orientation of the international review team (IRT)

The peer review will kick-off with an orientation meeting for the international review team in order for the reviewers to:

- get acquainted with the NEA peer review methodology and concept and learn what is expected from the international review team;
- get know one another better;
- receive an oral introduction to the review material and get to know their counterparts;
- decide on an internal *modus operandi* and schedule to move ahead.

2.2.2 Request for information

The first step for the peer reviewer is to secure information about the facility in order to begin the process of preparing the international review team for its examination of the data. The peer review will only start once all documentation that is agreed upon in the ToR of the review has been received.

At the start of the review, while the reviewers are still familiarising themselves with the review materials, the reviewee will be asked to provide responses to the pre-prepared checklists presented in the following sections of this report.

It is important to note that these suggested checklists are intended as a starting point for the review. Although the questions only elicit a "yes" or "no" answer, the reviewee can also provide additional information.

Upon examination of the peer review documents and the responses to the checklist questions, the IRT will generally prepare and submit additional, more specific questions by mail.

2.2.3 Review workshop

The next step is a one-week review workshop conducted through open, face-to-face meetings with the cost estimate preparation team so as to better understand how the estimate was prepared and to clarify any questions in the supporting information and underpinning data. This step necessitates the availability of facility personnel to answer questions and thus would need to consider their other plant operation responsibilities. The agenda for the workshop will typically make clear who should be available and when.

The IRT will maintain documentation of all responses to verbal questions. The "yes," "no," or "not applicable" format of the checklists will be supplemented, within the IRT, by written remarks as applicable.

2.2.4 Consolidation of IRT views

Following the one week workshop, the IRT will gather their individual comments and share them with each other in order to consolidate them into a comprehensive list. The comments may be organised into similar or associated issues. Generally, a single IRT reviewer is internally responsible for gathering the agreed upon comments and views in order to provide consistency in format and writing style.

2.2.5 Draft review report

The IRT will iterate internally to arrive at a draft review report. Once there is concurrence within the IRT that the report has the necessary level of quality vis-à-vis the agreed upon ToR, the draft report will be forwarded to the reviewee for comments and to allow for the clarification of any factual inaccuracies.

A procedure will be implemented within the IRT to ensure that the reviewee's comments are received and processed. A "comment resolution form" may be foreseen.

2.2.6 Final report

Upon full agreement within the review team, the final report will be sent to the reviewee by the NEA. The report may or may not be released publically, in accordance with the ToR for the review.

3. Reviewing the contents of a cost study report

The approach selected for conducting the peer reviews is to develop a series of checklists to guide the IRT in evaluating the quality and content of cost estimates.[1] It is important to note that these suggested checklists are intended as a starting point for the review, and additional questions are expected to be generated as the IRT progresses with the review. The checklists are not intended to be prescriptive or limiting.

This chapter of the guide addresses the review of the quality of the estimate for completeness and accuracy, while the comparisons to international benchmarks for validation of the results are addressed in Chapter 4.

3.1 Statement of the class of the estimate

The report should state the estimator's confidence in the accuracy of the results. A common way to do this is to state the classification of the estimate, for instance, in accordance with national or international guidance. Tables 1-3 of *The Practice of Cost Estimation for Decommissioning Nuclear Facilities,* [2] provide examples of classification systems in use. An estimate is assigned a class based on the status of the facility or maturity of the estimate (conceptual, feasibility, budgetary, control or check estimate/bid-tender). Table 1 summarises the AACEI classifications and estimate status.

Table 1: Estimate classifications checklist

	Yes	No	n/a
Class 5 – concept screening			
Class 4 – study or feasibility			
Class 3 – budget authorisation or control			
Class 2 – control or bid/tender			
Class 1 – check estimate or bid/tender			

1. The reviewer should perform a preliminary screening of the content of the report to ensure all major elements are included. If there are significant deficiencies, the reviewer should notify the estimate originator (applicant/owner/licensee and/or estimating consultant) in writing as soon as possible. If the deficiencies cannot be corrected quickly, the reviewer must assess whether to postpone the review and wait for the revised version, or continue reviewing without all the information needed for a fair assessment and evaluation.

3.2 Purpose and scope identified

The reviewer should ensure that there is a clear statement of the purpose of the study and the scope of work in the report. Table 2 provides a checklist of the significant points that should be addressed in the report.

Table 2: Purpose and scope checklist

	Yes	No	n/a
Purpose and scope is clearly defined			
Prerequisites are identified			
Estimate exclusions and boundary conditions are identified			
The end point criteria and end-state is indicated and is reasonable			
Vetted and approved by management, contract agreement, or regulatory requirements			
Budget constraints (if any) are stated and defined			

3.3 Legal and regulatory framework for decommissioning

The reviewer should be informed that the appropriate government regulatory requirements are referenced in the report. The reviewer should be informed about the basic responsibilities of the government, relevant ministry(ies), regulators (nuclear, public health, industrial safety, others), licensee, owner and decommissioning operator in the industrial segment of decommissioning. The reviewer should also be informed about the most important parliamentary acts, departmental and regulator's decrees and guidance related to decommissioning to check appropriateness of references in the report.

Table 3: Regulatory requirements checklist

	Yes	No	n/a
Acts, relevant departmental ordinances/decrees and regulator's decrees and guidance relevant to decommissioning:			
1. Decommissioning licensing			
2. Decommissioning operation			
3. Site release after decommissioning			
4. Radiation protection, public health, health and safety			
5. Material clearance, reusable material and waste management			
6. Environmental protection, environmental impact assessment			
7. Industrial safety and fire protection			
8. Civil construction			
9. Area and landscape development, nature and heritage protection			

3.4 Decommissioning strategy by phase

The reviewer should be informed of the decommissioning strategy considered in the study. Table 4 lists IAEA defined strategies by name and the key elements constituting their implementation.

Table 4: Decommissioning strategy by phase checklist

	Yes	No	n/a
Immediate dismantling strategy			
Phase 1 – preparations			
Engineering and planning – feasibility studies, licensing, permits and procedure preparation			
Site preparations – facility shutdown activities, legacy waste disposal, draining/deactivating systems			
Phase 2 – decommissioning operations			
Construction of temporary facilities to support decommissioning			
Reconfiguration/modification of site structures and facilities to support decommissioning			
Design and fabrication of shielding and special tooling			
Procurement of transport canisters, cask liners, industrial packages			
Decontamination of piping, components and contaminated concrete surfaces			
Removal of piping and components not required to support decommissioning			
Steam generators, pressurisers, reactor coolant/recirculation pump removal and disposition			
Reactor vessel internals segmentation and disposition			
Reactor vessel segmentation/one-piece removal and disposition			
Demolition of the biological shield, fuel storage and service pools			
Removal of contaminated turbine-generator, condenser and feedwater system components			
Final site radiological survey for license termination			
Submittal of all licensing documentation for license termination			
Phase 3 – conventional demolition and site restoration			
Demolition and removal of all remaining site buildings and structures			
Restoration of the site			

Table 4: Decommissioning strategy by phase checklist *(Cont'd)*

	Yes	No	n/a
Deferred dismantling strategy			
Phase 1 – preparations			
Engineering and planning – feasibility studies, licensing, permits, and procedure preparation			
Site preparations – facility shutdown activities, legacy waste disposal, draining/deactivating systems			
Draining of the reactor vessel with internals in place and vessel head secured			
Draining and deactivation of non-essential systems not required to support safe enclosure			
Decontamination of building access pathways for periodic inspections during safe enclosure			
Preparing lighting systems, security, electric power and heating/ventilation systems for safe enclosure			
Conducting radiation surveys of plant status for posting of warning signage			
Phase 2 – safe enclosure			
Perform surveillance and maintenance of power, lighting, security, environmental monitoring systems			
Conduct periodic radiation and environmental monitoring surveys and report results to regulators			
Phase 3 – delayed dismantling			
Engineering and planning – feasibility studies, licensing, permits, and procedure preparation			
Site preparations – modifications to security, access roads, gates, lighting, HVAC and power supplies			
Decontamination, removal, transport, disposal of all systems/structures as in immediate dismantling			
Phase 4 – conventional demolition and site restoration			
Demolition and removal of all remaining site buildings and structures			
Restoration of the site			

3.5 Project management approach

The reviewer should verify that the report identifies whether decommissioning will be managed as an applicant/owner/licensee self-directed project, or managed by a decommissioning operations contractor (DOC) under applicant/owner/licensee oversight. For the applicant/owner/licensee scenario, the full responsibility of costs and risks lies with the applicant/owner/licensee. In the DOC scenario, if the DOC is contracted under a time-and-materials arrangement, in that case DOC does not take responsibility for the costs and risks. If the DOC is contracted under a fixed-price/lump sum contract, or under a cost plus incentive fee contract, the

DOC assumes all responsibility for the costs and risks. Table 5 provides guidance on the functional responsibilities/positions of the management staff for each scenario.

Table 5: Project management approach checklist

	Yes	No	n/a
Applicant/owner/licensee self-directed management			
Mobilisation and preparations			
Project management			
Project planning and ongoing implementation			
Cost and schedule controls			
Safety and environmental controls			
Quality assurance and quality control			
Administration and accounting			
Public relations and stakeholder involvement			
Support services			
Engineering – mechanical, civil, electrical, environmental, instrumentation, structural			
Information systems and computer support			
Waste management			
Decontamination, chemistry support			
Decommissioning operations			
Personnel management and training			
Document control and records retention			
Procurement, warehousing, materials handling			
Housing, office equipment and support services			
Overhead expenses for central (home) office support			
Collateral costs for procurement of heavy equipment, special tooling, laundry service			
Health physics and safety			
Health physics services, radiation control			
Industrial safety			

Table 5: Project management approach checklist *(Cont'd)*

	Yes	No	n/a
Mobilisation/demobilisation			
Mobilisation of temporary facilities, telephone, internet, trailers, laundry			
Demobilisation of all temporary facilities at project completion			
Specialty contractors			
Decontamination – chemical, mechanical concrete scabbling			
Vessel and internals segmentation			
Steam generator, pressuriser, reactor coolant/recirculation pump removal			
Demolition – concrete and steel structures			
Site restoration – backfill, earthmoving, grading, landscaping			
Health physics, radiation control, laboratory services			
DOC management			
Applicant/owner/licensee oversight services			
Project management oversight			
Project cost and schedule control			
Procurement and contracting (of DOC)			
Quality assurance			
Health physics and industrial safety			
Administration, accounting and financial			
Licensing			
Environmental impacts			
Public relations and stakeholder involvement			
Overhead expenses for central (home) office support			
DOC management services			
Mobilisation and preparations			
Project management			
Project planning and ongoing implementation			

Table 5: Project management approach checklist *(Cont'd)*

	Yes	No	n/a
Cost and schedule controls			
Safety and environmental controls			
Quality assurance and quality control			
Administration and accounting			
Support services			
Engineering – mechanical, civil, electrical, environmental, instrumentation, structural			
Information systems and computer support			
Waste management			
Decontamination, chemistry support			
Decommissioning operations			
Personnel management and training			
Document control and records retention			
Procurement, warehousing, materials handling			
Housing, office equipment and support services			
Overhead expenses for central (home) office support			
Collateral costs for procurement of heavy equipment, special tooling, laundry service			
Health physics and safety			
Health physics services, radiation control			
Industrial safety			
Mobilisation/demobilisation			
Mobilisation of temporary facilities, telephone, internet, trailers, laundry			
Demobilisation of all temporary facilities at project completion			
Specialty contractors			
Decontamination – chemical, mechanical concrete scabbling			
Vessel and internals segmentation			
Steam generator, pressuriser, reactor coolant/recirculation pump removal			
Demolition – concrete and steel structures			
Site restoration – backfill, earthmoving, grading, landscaping			
Health physics, radiation control, laboratory services			

3.6 Assumptions

The reviewer should check that the key assumptions for the estimate are clearly listed in the report. Since site-specific cost estimates deal with the actual conditions existing or predicted to exist at the facility, any assumptions used must also be site-specific. Table 6 provides a list of typical assumptions for the immediate dismantling strategy as an indication of the level of detail that should be addressed. The scenario presented is for an applicant/owner/licensee oversight of a DOC. It is not intended to be prescriptive or limiting.

Table 6: Assumptions checklist

	Yes	No	n/a
Licensing, permits, insurance			
All licensing documentation will be prepared by applicant/owner/licensee and submitted to regulatory agencies			
Regulatory agencies will not impose unforeseen delays on the start of the work			
Applicant/owner/licensee to provide all facility licenses, permits, and insurance (decreasing with phase)			
Site preparations			
DOC will prepare all work plans for the implementation of decommissioning			
Applicant/owner/licensee will provide electrical power, water and legacy waste disposition as needed			
Electric power costs for decommissioning (lighting, tooling, ventilation, etc.) are included in estimate			
Applicant/owner/licensee will drain all contaminated liquids from piping/components and dispose of the liquids			
DOC will remove and dispose of all asbestos in accordance with applicable procedures			
Applicant/owner/licensee states there are no known areas of soil or groundwater contamination			
Applicant/owner/licensee will provide approved location for delivery/storage of diesel fuel for heavy equipment			
Applicant/owner/licensee will provide radiological dosimetry and health/safety oversight for all on-site personnel			
Applicant/owner/licensee will provide an industrial safety specialist for oversight of the project			
DOC will provide crew with all protective clothing, respiratory equipment and laundry services			
Applicant/owner/licensee will erect physical barriers and/or secure access to radioactive/contaminated areas			
DOC will provide all health physics/radiation control technicians for the hands-on work			

Table 6: Assumptions checklist *(Cont'd)*

	Yes	No	n/a
DOC will provide workers compensation insurance for crew and general liability insurance for project			
Facility dismantling			
DOC will be the principal contractor for this work. Selected subcontractors will be retained as needed			
Unit cost factors (UCFs) based on applicant/owner/licensee provided labour rates for all classes of labour/staff			
UCFs include overhead and profit on materials and supplies			
UCFs incorporate work difficulty factors (WDFs)			
UCFs are based on protective clothing (PPE) changes four times per day			
UCFs are based on packaging factor void percentage of 10% to 30% for all transport containers			
UCFs are based on a transport time to the disposal facility			
UCFs are based on non-contaminated waste being placed in roll-off containers for landfill disposal			
UCFs are based on LLW and ILW placed in half-height/full-height ISO containers for disposal			
Materials suitable for scrap or salvage have been accounted for			
No credit for sale of scrap/salvage has been assumed			
All LLW and ILW will be transported by ship for final disposal			
DOC will provide the final site survey and all necessary documentation to regulatory agencies			
Applicant/owner/licensee will provide oversight of the final site survey and documentation			
Conventional demolition and site restoration			
Non-contaminated or decontaminated buildings/structures will be demolished to 1m below grade			
All below-grade voids (building basements) will be backfilled with clean fill and compacted			
Clean concrete rubble will be used as fill			
All excavations will be re-graded to a final contour consistent with adjacent surroundings			
Any affected areas from building demolition and backfill will be covered with loam and seeded			
Furniture, tools, mobile equipment (forklifts, trucks, bulldozers) will be removed at no cost or credit			

3.7 Cost estimating methodology

The report should state the cost estimating methodology applied for the estimate and identify the most common types of cost estimating methods and cases where they may be applied [1].

A common methodology is the unit cost factor approach, which is the methodology developed by the Atomic Industrial Forum (now the Nuclear Energy Institute) in its document, "Guidelines for producing commercial nuclear power plant decommissioning cost estimates," for use by US nuclear power plant licensees [4]. Table 7 provides a list of methodologies and key information that should be included with the methodology.

Table 7: Cost estimating methodology checklist

	Yes	No	n/a
Bottom up technique			
Is a work statement provided?			
Are drawings/specifications used to extract material quantities requiring dismantling/removal?			
Are UCFs (costs per unit of productivity) applied to these quantities to determine the cost for removal?			
Are direct labour, equipment, consumables, and overhead incorporated into the unit cost factors?			
Are costs reported in local currency for the current (or previous) years?			
Specific analogy			
Are the known costs of an item in prior estimates used for the cost of a similar item in a new estimate?			
Are adjustments made to known costs in order to account for differences in size, weight, and configuration?			
Are costs reported in local currency for the current (or previous) years?			
Parametric			
Are costs based on historical databases of similar systems or subsystems and structures?			
Are statistical analysis performed on data for correlations between cost drivers and other parameters?			
Are parameters based on units of inventory per item, or per square/cubic metres, per kilogrammes?			
Have analyses produced cost equations/relationships used individually or grouped in complex models?			
Cost review and update			
Was the estimate constructed by examining previous estimates of the same or similar projects?			

Table 7: Cost estimating methodology checklist *(Cont'd)*

	Yes	No	n/a
Was the estimate checked for internal logic, complete scope, assumptions, estimating methodology?			
Expert opinion			
Were several specialists consulted iteratively until a consensus cost estimate was established?			
Are the credentials of the specialists identified in their respective areas of expertise?			
Are curriculum vitae provided for each specialist?			

3.8 Physical description of the facility and characterisation data

The physical description of the facility (and its radiological and hazardous/toxic material inventory) is the heart of the bottom-up estimating methodology. In practical terms, it is the most time-consuming part of developing a site-specific estimate. The credibility of the estimate hinges on the completeness of the data that represents the facility to be decommissioned. The physical inventory of piping, valves, pumps, tanks, heat exchangers, ducting, electrical cable and conduit, electrical switchgear and building structures must be accounted for in a rigorous fashion to ensure the facility is properly represented. To this end, current drawings, equipment specifications and operating manuals should be used to extract data on lengths, numbers of units, weights, volumes, configuration, and size limitations (for removal through existing doorways or hatches). Often a site visit is required to verify whether new equipment or structures have been added since the last drawing update, or whether unused redundant equipment has been removed.

Similarly, the radiological and hazardous/toxic material inventory must be identified to accurately represent the conditions that precede and drive decommissioning decisions. For a permanently shut down facility, the site characterisation report should be consulted to determine the levels of radiological contamination, activation of the reactor vessel and high radiation areas requiring restricted access and decontamination. Similarly, a listing of hazardous/toxic materials is necessary to address asbestos, legacy chemicals and spills that may not have been fully cleaned. For a facility still in operation, current operating radiological records may be used to determine the foregoing information, supplemented by calculated levels of vessel activation that assumes operation through the full license life of the facility.

The cost estimate may follow the *International Structure for Decommissioning Costing of Nuclear Installations* (ISDC) format or the work breakdown structure (WBS) format. The details of the inventory should be listed by system and structure in both approaches. Alternatively, any format that addresses all the equipment and structures in a logical, complete manner may be used. The reviewer should be cognizant of the format applied to ensure the inventory is properly included.

Table 8 provides a sample list of the systems and structures that should be accounted for in the estimate. As this information is site-specific, the reviewer needs to become familiar with the facility systems and structures. A site visit can provide significant insight as to the arrangement, degree of difficulty and special considerations associated with decontamination, removal and disposition of the materials.

Table 8: Physical description of the facility and characterisation data checklist

	Yes	No	n/a
Facility physical description			
Are the following systems and structures addressed in the estimate?			
Ion exchangers and resins			
Spent fuel racks			
Boron injection system and boron waste			
Chemical and volume control			
Safety injection system			
Residual heat removal system			
Spent fuel pool cooling system			
Reactor pressure vessel (RPV) internals			
Contaminated cranes			
Radiological decontamination, removal, and packaging of spent fuel pool liner			
Removal of reactor coolant system (RCS) piping and equipment			
Removal of pressuriser and relief tank			
Removal of steam generators and blowdown system			
Removal of control rod drive system			
Segmentation and packaging of reactor pressure vessel			
Bio-shield shield			
Post-accident sampling system			
Main steam piping, valves and controls			
Turbine generator(s)			
Turbine gas (hydrogen) system			
Turbine generator hydrogen seal oil system			
Turbine generator stator cooling			
Turbine lube oil storage, filtration and cooling			
Turbine condenser(s)			
Turbine plant sampling system			
Moisture separator reheaters			

Table 8: Physical description of the facility and characterisation data checklist *(Cont'd)*

	Yes	No	n/a
Feedwater heaters, drains and vents			
Auxiliary feedwater system			
Feedwater condensate system and chemical injection			
Feedwater pumps/turbine drives			
Condensate filter demineraliser			
Condensate air injection			
Extraction steam system			
Auxiliary gas system			
Auxiliary steam system			
Circulating water system and chemical injection			
Engineered safety system room coolers			
Plant makeup water treatment, storage and degas system			
Component cooling water			
Auxiliary component cooling water			
Chilled water system			
Containment spray system			
Containment air purification and clean-up system			
Floor drains – all buildings			
Diesel generator			
Electrical switchgear and control equipment			
Fire protection system			
Service air system			
Instrument air system			
Plant demineralised water system			
Potable water system			
Radioactive waste solidification and volume reduction equipment			
Waste processing – gas			
Waste processing – liquid			
Sewage treatment system			
Contaminated concrete			
Heating, ventilation and air conditioning (HVAC) ducts and equipment – all buildings			

Table 8: Physical description of the facility and characterisation data checklist *(Cont'd)*

	Yes	No	n/a
Demolition of remaining site buildings and structures			
Are the following systems and structures addressed in the estimate?			
Reactor containment			
Auxiliary (including operational waste management facilities)			
Circulating water intake canal			
Control			
Cooling tower – hyperbolic/mechanical			
Diesel generator			
Miscellaneous buildings and tanks			
Station tunnels			
Turbine building and pedestal			
Fuel handling			
Surface and groundwater			
Contaminated soils			
Radiological and hazardous materials			
Are systems/structures categorised in accordance with respect to levels of contamination/activation?			
Was the categorisation used as a basis for disposition of the equipment and structures?			
Was the categorisation of the reactor vessel and internals activation used as a basis for disposition?			
Were the levels of contamination used as a basis for applying work difficulty factors (WDFs)?			

3.9 Quality of the data

The quality of the data refers not only to that listed in Table 9 for the source of the information, but also to the source of information used to develop unit cost factors, packaging information, transportation and storage/disposal costs. If anything other than a bottom-up estimating method is used, or the source is reference plant information, it is important to validate the accuracy of the estimate. Table 9 provides the reviewer with guidance as to the assessment of the quality of data.

Table 9: Quality of data checklist

	Yes	No	n/a
Physical source data of the facility			
Are all physical data references listed as to the source of the data?			
Are the physical data references based on site-specific drawings, specifications or operating manuals?			
Was a site visit/tour performed by the estimating team to familiarise themselves with the facility?			
Is there a clear statement as to the source of cost data for waste packaging, transport and storage/disposal?			
Is there a clear statement as to the source of cost data for radiological/hazardous equipment/structure removal?			
Is there a clear statement as to the source of cost data for non-radiological equipment and conventional demolition?			
Does the estimator's quality assurance programme require checking of the input data to cost estimate codes?			
Radiological and hazardous source data			
Was a facility characterisation report used to identify sources, concentrations, radiation levels in the facility?			
Was a facility characterisation report used to identify sources, concentrations of hazardous/toxic materials?			
If no characterisation report was used, does the estimate state how radiological/hazardous conditions were estimated?			
If references were used, are they clearly stated/provided in the estimate?			
Do the references represent the current state of the knowledge data?			
Bottom-up UCF based estimates			
Are the UCFs based on local labour, equipment and materials costs?			
If non-local labour, equipment, material costs were used, were appropriate cost indices/exchange rates applied?			
Do the UCFs provide the basis for productivity rates (cost/kg, etc.) from actual field data from projects or vendors?			
Do the UCFs describe the task activities to perform a given removal/decontamination sequence?			
Do the UCFs allow for parallel task activities without a serial increase in task duration (i.e. critical path work)?			
Are the UCFs adjusted for work difficulty factors (WDF) to account for site-specific conditions in the facility?			
Is there a clear statement of which WDFs were applied and under what conditions?			
Is the UCF task crew clearly identified by worker category and labour rate?			

Table 9: Quality of data checklist *(Cont'd)*

	Yes	No	n/a
Are the appropriate labour rates applied to the WDF adjusted durations to develop the task labour cost?			
Are equipment and consumables identified and costed, with an appropriate mark-up for overhead and profit?			
Is total cost of labour and equipment/consumables for the sequence divided by the productivity parameter (kg, m)?			
Is a summary listing of UCFs used in the estimate provided (there may be more than one set for different WDFs)?			
Is there a general description of how the estimator's computer code combines the inventory with the UCFs?			

3.10 Dismantling sequence and approach

The dismantling sequence and approach is key to a logical progression of activities, taking into account predecessor-successor events and potential delays related to securing regulatory approvals or other time-dependent events. The sequence drives the duration of the hands-on work, which sets the overall schedule for the project. The period-dependent project management costs are then related to the overall schedule. Table 10 provides the reviewer with guidance for evaluating the reasonableness of the sequence.

Table 10: Dismantling sequence and approach checklist

	Yes	No	n/a
Does the estimate provide a written sequence of activities for the selected decommissioning strategy?			
Is sequence in the form of written text, a PERT (programme evaluation and review technique) chart, or a Gantt chart?			
Is the sequence presented in chronological order consistent with the baseline cost estimate?			
Are multiple paths identified to show parallel work activities to minimise the overall duration of the schedule?			

3.11 Baseline schedule estimate

The baseline schedule estimate should follow the same level of underpinnings as the cost estimate as far as assumptions, WBS format and logic. Most scheduling programmes offer a predecessor-successor network sequencing of activities in either a programme evaluation and review technique (PERT) format, or a Gantt chart format. The typical scheduling programmes are Oracle's Primavera P6 and Microsoft Project. Other programmes may also be used. The estimator plans the activities to minimise the critical path of the programme to reduce the overall duration, and should perform a critical path analysis to ensure the shortest schedule. The estimator should also evaluate whether the individual and total float can be minimised. Table 11 provides the reviewer with a checklist for evaluating the baseline schedule estimate.

Table 11: Baseline schedule estimate checklist

	Yes	No	n/a
Does the estimate include a schedule with WBS elements linked to the cost estimate?			
Is the critical path of the schedule included on the PERT or Gantt chart?			
Is the dismantling sequence consistent with that of the "Dismantling Sequence and Approach" table?			
Was the schedule estimate developed using approved software (P6, Microsoft Project, etc.)?			
Is programme "float" identified (the time a task in a network can be delayed without delaying other tasks or completion)?			
Is there discussion as to how float may be minimised?			
Has a critical path analysis been performed to shorten the overall schedule?			

3.12 Contingency

According to ISDC [1], contingency is a recognised cost, fully expected to be spent. The concept of contingency is to allow for unexpected events within the defined project scope.

Contingency is defined by the AACEI [5] as "a specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events that increase costs are likely to occur." Indeed, as with any major project, events occur that are not accounted for in the base estimate. Therefore, a contingency factor needs to be applied.

The methods for accounting for contingency vary from one estimator to another. The method for application of contingency should be clearly stated and explained. It may be a single-valued percentage based on the total cost of the project, or a multi-valued percentage applied to each line item of the estimate. Some estimators use the risk analysis to determine the contingency. Table 12 provides the reviewer with a checklist to evaluate how the contingency was applied.

Table 12: Contingency

	Yes	No	n/a
Does the estimate include contingency?			
Is the definition of contingency included in the report?			
Is the contingency stated as an overall single-valued percentage?			
Is the single value basis justified by reference?			
Is contingency calculated on a line-item basis (individual contingency % for each element of cost)?			
Are the percentages for contingency elements explained?			
Are the contingency percentage bases identified (by reference source or by committee judgement)?			
Was contingency developed using the risk analysis?			
Does the report identify how contingency was developed from the risk analysis?			

3.13 Allowances

Allowances are specific provision for an activity or expense that is known will be incurred, but whose actual cost is not sufficiently determined. This allowance would be included based on best judgement or best available information

The methods for accounting for allowances include estimator's judgement from prior experience, vendor quotes of budgetary costs or parametric estimates from previous projects. The method for estimation of allowances should be clearly stated and explained. Table 13 provides the reviewer with a checklist to evaluate how the contingency was applied.

Table 13: Allowances

	Yes	No	n/a
Does the estimate include allowances?			
Is the definition of allowances included in the report?			
Are the allowances stated as a lump-sum cost value or a percentage of another parameter (labour, materials, equipment)?			
Is the single value lump-sum basis justified by reference?			
Are the percentages for allowances explained?			

3.14 Risk analysis

The project risk analysis addresses out-of-scope uncertainties and provides a level of confidence that the estimate will adequately bound the costs and schedule, taking into account potential events that could increase costs and delay the schedule. The risk analysis should also identify potential opportunities that could reduce costs and accelerate the schedule. The process described in *The Practice of Cost Estimation for Decommissioning Nuclear Facilities* [2] includes conducting a risk workshop to identify risks and opportunities, categorising the level of risk and preparing a risk register (a list of all potential risks and opportunities). The risk register should include an evaluation of methods to reduce risk or to enhance opportunities. If a quantitative risk analysis was prepared, generally accepted computer codes should be used. Table 14 provides the reviewer with a checklist to evaluate the risk analysis.

Table 14: Risk analysis

	Yes	No	n/a
Does the estimate include a risk analysis?			
Was a risk workshop convened by the estimator to identify all potential risks and opportunities in a risk register?			
Is there evidence that a risk mitigation evaluation was made?			
Was a quantitative risk analysis performed using a Monte Carlo based computer program?			
Was Monte Carlo analysis performed using approved software (PertMaster, Crystal Ball, @Risk, ModelRisk, etc.)?			
Was a triangular distribution assumed?			
If a triangular distribution was used, are the low, most likely (baseline estimate), and high values explained?			
Is a different distribution used (double triangular, Bernoulli)?			
Were opportunities included in the quantitative risk calculation?			
Does the risk analysis identify the P50 and P80 probabilities of costs?			
Does the risk analysis include a sensitivity analysis (tornado chart) of major cost drivers?			
Does the risk analysis include a cumulative probability curve?			
Was the risk analysis used to determine the contingency?			

3.15 Decommissioning techniques and technologies employed

The decommissioning techniques and technologies employed for the purpose of an estimate can have a major influence on the success of the project, the overall schedule and costs. For example, selecting a slow cutting technology for the reactor vessel internals can result in greater direct costs (if contracted on a cost plus incentive fee basis) and extend the project duration, thereby increasing the project management costs for the contractor, the DOC and the applicant/owner/licensee. In general, for routine cutting of piping/components and the demolition of concrete/steel structures, the estimate should be based on proven technologies and techniques where representative cost data is available from vendors if possible or reasonable representations can be made based on published information.

A different approach may be used for more difficult tasks. For example, segmenting the reactor vessel internals is one of the most difficult tasks, yet does not lend itself to unit cost factor approaches. The technologies used in the past include plasma arc cutting, high-pressure abrasive water jet cutting and mechanical cutting. Contractors using these techniques have all encountered numerous, costly problems resulting in project delays. Estimators typically will use the field experience of the longest duration of any of the technologies used, and a fixed field crew for all cutting. This type of estimating is called level-of-effort since the crew cost per hour (day, week) is set and the duration determines the labour cost. An allowance is included for equipment and consumables as appropriate. No specific technology is specified, as individual contractors will use their creativity to select one. Table 15 provides the reviewer with guidance on how to evaluate the technologies considered in the estimate.

Table 15: Decommissioning techniques and technologies employed checklist

	Yes	No	n/a
Does the estimate describe the techniques/technologies expected to be used in decommissioning?			
For decontamination of piping and components, are specific decontamination technologies identified?			
Does the estimate identify productivity rates (decontamination factors – DFs) for these technologies?			
Are these DFs based on actual field data or vendor estimates/quotes?			
For cutting piping, components, ducting, electrical cable, are specific proven technologies identified?			
Are these technologies identified in the UCFs as part of the task description for aforementioned work?			
Are technologies identified for reactor vessel and internals segmentation/removal?			
Is the estimate for reactor vessel and internals done on a UCF or level-of effort basis?			
If a UCF basis, does the estimate identify the source of productivity rates assumed for the current estimate?			
If a level-of-effort basis, does the estimate identify the source of crew size/composition and duration assumed?			
For demolition of concrete and steel structures, are proven techniques identified?			
Are productivity rates for these techniques based on actual field data, vendor quotes or handbook data?			
For the final site survey, does the estimate identify the basis (MARSSIM or other) used for survey time/cost?			

3.16 Baseline cost estimate

This section of the guide provides the reviewer with a checklist to ensure the baseline estimate is complete. Table 16 lists the major elements of the baseline cost estimate.

Table 16: Baseline cost estimate checklist

	Yes	No	n/a
Does the estimate use a work breakdown structure (WBS) or ISDC or other reasonable basis?			
Does the WBS include a dictionary describing each activity?			
Does the WBS include a list of abbreviations and acronyms used in the estimate report?			
Does the estimate include a table of costs by phase for each decommissioning strategy?			
Does the estimate list all of the systems and structures shown in checklist Table 9?			
Does the estimate list costs down to WBS Level 3 as a minimum?			
Are project management costs identified in the estimate by phase?			
Are all overhead costs for project management and contractor labour costs included?			
Are licensing and regulatory issues described in the report and appropriate costs included?			
Are stakeholder concerns identified in the report?			
Are allowances included for the costs of conducting stakeholder information meetings?			
Are waste management considerations for LLW, ILW and spent nuclear fuel included in the report?			
Are the costs for disposal of LLW and ILW identified in the report and costs broken down appropriately?			
Are site restoration considerations included in the report?			
Are regulatory end-state, site-clearance and exemption considerations included in the report?			
Are facility re-use considerations included in the report?			
If site re-use is included, is a credit included in the cost estimate?			
If an EVMS is assumed to be applied in decommissioning, are costs included?			
Are all references used to develop the estimate included in the report?			

4. Comparing with other estimates – benchmarking

The comments regarding benchmarking in *The Practice of Cost Estimation for Decommissioning Nuclear Facilities* [2] are provided as a caution regarding over-reliance on the accuracy or comparability of cost data from international sources.

As noted earlier, obtaining accurate, representative cost data from completed projects is difficult. Contractors consider this experience to be proprietary, and applicants/owners/licensees are not willing to share such information if in fact they tracked the costs to any level of detail or accuracy. With these caveats, it may still be reassuring to compare cost estimates to actual decommissioning experience in order to provide a level of validation not otherwise possible.

4.1 Similar facilities – size and complexity

The first and obvious consideration is to ensure the benchmarked facility is similar in design, size and complexity to the estimate under review. The differences posed by projects at single-unit sites versus multi-unit sites can raise significant problems in attempting to compare costs. Table 17 provides the reviewer with a checklist of considerations to examine for PWRs and BWRs.

Table 17: Similar facility – size and complexity checklist

	Yes	No	n/a
Pressurised water reactors – PWRs			
Is the benchmark reactor a single-unit site or multi-unit site?			
Assuming a single-unit site, what is the megawatt rating?			
Is the difference in megawatts of the benchmark to existing reactor more than a factor of 10?			
Are the number of steam generators the same?			
Are the number of reactor coolant pumps the same?			
Are the operating histories similar?			
Do the benchmark actual costs include the costs for handling and storage of spent nuclear fuel?			
Is there sufficient detail to delete spent fuel handling/storage costs?			
Do the benchmark actual costs include costs for packaging, transporting and disposal of LLW and ILW?			
Is there sufficient detail to separate the costs for packaging, transporting and disposal of LLW and ILW?			

Table 17: Similar facility – size and complexity checklist *(Cont'd)*

	Yes	No	n/a
Is the containment building of the benchmark plant similar in design to the plant in review?			
Are there separate buildings for fuel, auxiliary, control, turbine-generator, diesel, security, administration, etc.?			
Did the benchmark plant have a single generator or multiple turbine-generators?			
Was there soil contamination at the benchmark plant?			
Was there groundwater contamination at the benchmark plant?			
Are the end point states similar – greenfield vs. brownfield?			
Were any buildings retained for re-use at the benchmark plant?			
Was the switchyard equipment retained for continued use at the benchmark plant?			
Boiling water reactor – BWR			
Is the benchmark reactor a single-unit site or multi-unit site?			
Assuming a single-unit site, what is the megawatt rating?			
Is the difference in megawatts of the benchmark to existing reactor more than a factor of 10?			
Does the benchmark reactor have recirculation pumps with or without jet pumps in the reactor vessel?			
Are the operating histories similar?			
Do the benchmark actual costs include the costs for handling and storage of spent nuclear fuel?			
Is there sufficient detail to delete spent fuel handling/storage costs?			
Do the benchmark actual costs include the costs for packaging, transport and disposal of LLW and ILW?			
Is there sufficient detail to separate the costs for packaging, transport and disposal of LLW and ILW?			
Is the benchmark containment building a Mark I (torus), Mark II (over/under) or Mark III (concrete circular pool)?			
Are there separate buildings for fuel, auxiliary, control, turbine-generator, diesel, security, administration, etc.?			
Did the benchmark plant have a single generator or multiple turbine-generators?			
Was there soil contamination at the benchmark plant?			
Was there groundwater contamination at the benchmark plant?			
Are the end point states similar – greenfield vs. brownfield?			
Were any buildings retained for re-use at the benchmark plant?			
Was the switchyard equipment retained for continued use at the benchmark plant?			

4.2 Adjustments for year of expenditure

Since recent decommissioning experience dates back as far as the early 1990s, adjustments for the year of expenditure are a necessary element of any comparison. Accounting for inflation during the period of completion of the benchmark plant basis and the estimate under review should take into account the cost elements of labour, materials, energy and transport/disposal of wastes. The US NRC's guidance for inflation adjustments provides an approach for a detailed comparison [2]. If the data is available, the benchmark breakdown into labour, materials, energy and transport/disposal of wastes can be individually escalated (inflated).[1] If detailed data is not available, the only recourse is to use an overall inflation rate for the difference in years in the comparison. A finer-tuned escalation would attempt to correct for inflation over the years of performance of the decommissioning project, as some projects have extended into decades of work. Generally, there is insufficient data available to perform these calculations. Table 18 provides the reviewer with a checklist of considerations in adjusting for inflation between comparative benchmarked costs.

Table 18: Adjustments for year of expenditure

	Yes	No	n/a
Is the year of the actual cost for decommissioning of the benchmark plant clearly stated?			
Is there a detailed breakdown of costs of the benchmark into labour, materials, energy and disposal?			
Can such a breakdown be assembled from the benchmark data provided?			
If source data is based on international resources for equipment and consumables, is the source identified?			
If source data is based on international currency, can costs be converted to local currency by exchange rate?			

4.3 Ten external factors for benchmarking

The NEA *Estimation of Nuclear Facility Decommissioning Costs – Current Status and Prospects* [6] indicates that, when comparing costs, "cost figures should not be taken at face value unless these (10) elements and their history are specified in comparative tables". The 10 elements are:

- scope of work through to the end point of the site;
- regulatory requirements, including details of reporting and clearance levels;
- stakeholders' demands;

1. Cost escalation is defined as changes in the cost or price of specific goods or services in a given economy over a given period. While escalation includes general inflation related to the money supply, it is also driven by changes in technology, practices, and particularly supply-demand imbalances that are specific to a good or service in a given economy.

- characterisation of physical, radiological and hazardous materials inventory;
- waste processing, storage and the availability of ultimate disposition facilities;
- disposition of spent nuclear fuel and onsite storage prior to emplacement in a permanent repository;
- clean structure disposition and disposal of the site for new developments;
- contingency application and use in estimates;
- availability of experienced personnel with knowledge of the plant;
- assumed duration of the dismantling and clean-up activities.

The benchmark analysis should also make reference to the above criteria.

5. Conclusions

Peer reviews have become a valuable tool to provide an independent assessment of the quality and completeness of decommissioning cost estimates. The practice has been used throughout the nuclear industry for safety reviews of operations, maintenance and decommissioning. With increasing importance being placed on decommissioning planning, funding and cost-effective implementation during decommissioning, the peer review process has gained renewed interest among utilities, government regulators and stakeholders. The NEA has experience in conducting peer reviews in radioactive waste management and nuclear R&D and has built on this experience to provide this guide, designed specifically for peer reviews of decommissioning cost estimate studies.

The approach described in the guide is essentially in the form of a roadmap to conduct peer reviews that are consistent from one peer review to another. Consistency is accomplished through the use of internationally developed checklists. It is also important to establish the credibility of the peer review approach and to gain the confidence of the reviewee, demonstrating that the findings and observations will provide constructive direction in order to achieve a quality cost estimate. Such an approach should also assist in establishing trend analyses which will help guide the industry in planning future decommissioning projects.

The checklists provided are not static, however, and as indicated in the report, should be adapted as each review team considers necessary.

6. References

[1] OECD/NEA (2012), *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations*, NEA No. 7088, Paris.

[2] OECD/NEA (2014), *The Practice of Cost Estimation for Decommissioning Nuclear Facilities,* (forthcoming), Paris.

[3] OECD/NEA (2005), *International Peer Reviews for Radioactive Waste Management,* NEA No. 6082, Paris.

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[5] *Cost Engineers' Notebook: American Association of Cost Engineers*, AA-4.000, p. 3 of 22, Rev. 2, January 1978.

[6] OECD/NEA (2012), Estimation of Nuclear Facility Decommissioning Costs – Current Status and Prospects, flyer, Paris.

7. Further reading

[1] Standard Review Plan for Decommissioning Cost Estimates for Nuclear power Reactors (2004), US Nuclear Regulatory Commission, NUREG-1713, Washington, DC, United States.

[2] *Common Summary Format for Decommissioning Cost Estimates* (2012), Nuclear Decommissioning Cost Triennial Proceeding, California Corporation Commission, Exhibit A.

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[8] *Project and Cost Engineers' Handbook*, Second Edition, (p 239), American Association of Cost Engineers (now AACEI), Marcel Dekker, Inc., New York, 1984.

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[12] Smith R.I et. al. (1978), Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station, Battelle Pacific Northwest Laboratory, NUREG/CR-0130, Vol. 1.

[13] Oak H.D. et al. (1980), Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, Battelle Pacific Northwest Laboratory, NUREG/CR-0672.

[14] US NRC, NRC Regulations, Title 10, Code of Federal Regulations, Part 50, Washington, DC, United States.

8. List of abbreviations and acronyms

AACEI	Association for the Advancement of Cost Engineering International
ASME	American Society of Mechanical Engineers
BWR	Boiling water reactor
DOC	Decommissioning operations contractor
EVMS	Earned value management system
IAEA	International Atomic Energy Agency
IRT	International review team
ISDC	International Structure for Decommissioning Costing of Nuclear Installations
NEA	Nuclear Energy Agency
NQA-1	Nuclear quality assurance -1 (ASME quality assurance programme)
NRC	(US) Nuclear Regulatory Commission
OECD	Organisation for Economic Co-operation and Development
PERT	Programme evaluation and review technique
PWR	Pressurised water reactor
P50/P80	Probabilities at the 50% and 80% confidence levels
UCF	Unit cost factor
WBS	Work breakdown structure
WDF	Work difficulty factor

Appendix A – Peer review team qualifications

In an ideal world, each reviewer would possess all the qualifications of those who prepared the cost estimates. This may not be reasonable, or necessary. Rather, the IRT members should have a strong background in the nuclear industry, some operating/decommissioning experience in power or research reactors, or nuclear fuel cycle facilities, and a general understanding of cost estimation. However, since decommissioning is a multi-faceted discipline involving engineering, planning, health and safety, cost estimating scheduling, risk analyses, operations, dismantling/demolition, waste management (packaging, transportation, storage, and disposal), and site restoration, the IRT should aspire to obtain as many of these attributes as possible in order to cover the spectrum of issues to be reviewed. Further, the experience base offered by these team members may include specific reference cost information that would allow for verification of proposed costs for various work activities. This may be obtained by a core group, say from the NEA, and supplemented by one or more outside consultants with specific experience. More specific, "ideal" qualifications are suggested in the following points.

1. General nuclear industry experience

Five or more years of work experience within the nuclear industry in a power plant, research reactor or nuclear fuel cycle facility. The experience may be from a management background or from a direct (hands-on) operations employment. Personnel with architect-engineer experience in design, construction, or decommissioning planning is also desirable. Regulatory experience from a government agency would make a very valuable contribution to the IRT.

2. Decommissioning experience – engineering and planning

Personnel with five or more years of decommissioning planning experience on any type of nuclear facility. Specifically, this experience would include all the documentation for licensing submittal or approvals, planning the activities to be performed, prioritising the work activities, and developing the labour and equipment resources needed to implement the project.

3. Health and safety

Ten or more years of experience in radiological and industrial health and safety work would be preferable on a decommissioning project. Decommissioning presents new challenges to the health and safety staff, not previously encountered during plant operations. Airborne, liquid, and solid waste conditions can change almost daily and can challenge the health and safety staff to maintain control of the processes. As cost estimates must include costs for protecting worker and public health and safety, the review team needs competent experience in this area.

4. Decommissioning cost estimation

Five or more years of decommissioning cost estimation experience, including scheduling and risk analyses. Experience has shown that a conventional cost estimator (even one certified by a recognised agency) generally does not have the understanding to integrate all the inter-related activities involved in decommissioning. Within the relatively short period allotted to most peer reviews, there is insufficient time to teach constructively newcomers how to provide in-depth reviews.

5. Decommissioning operations

Ten or more years of experience in field operations for decommissioning projects. As the old expression goes, "there is nothing better than first-hand experience." As decommissioning activities involve many disciplines of planning, purchasing (critical equipment), scheduling and safety of the workers and the public, hands-on experience is strongly recommended to support the IRT.

6. Waste management

Ten or more years of experience in waste management activities, with a heavy emphasis on hands-on experience. Waste management involves packaging, transport and disposition, requiring a full knowledge of available licensed packaging containers, transport methods and routes, transport conditions related to public concerns and disposal site Waste Acceptance Criteria (WAC). If the waste does not meet the WAC, it cannot be disposed of in that facility. The results of the characterisation report must be reviewed and understood so that effective planning can be undertaken.

7. Dismantling and demolition

Ten or more years of experience in dismantling equipment and in the demolition of structures. This experience is invaluable in assessing whether proposed methods and specific equipment is suitable to safely accomplish the proposed activities.

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Guide for International Peer Reviews of Decommissioning Cost Studies for Nuclear Facilities

Peer reviews are a standard co-operative OECD working tool that offer member countries a framework to compare experiences and examine best practices in a host of areas. The OECD Nuclear Energy Agency (NEA) has developed a proven methodology for conducting peer reviews in radioactive waste management and nuclear R&D. Using this methodology, the NEA Radioactive Waste Management Committee's Working Party on Decommissioning and Dismantling (WPDD) developed the present guide as a framework for decommissioning cost reviewers and reviewees to prepare for and conduct international peer reviews of decommissioning cost estimate studies for nuclear facilities. It includes checklists that will help national programmes or relevant organisations to assess and improve decommissioning cost estimate practices in the future. This guide will act as the NEA reference for conducting such international peer reviews.

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