IAEA Nuclear Energy Series

No. NW-T-2.1

Basic Principles

Objectives

Guides

Technical Reports

Selection and Use of Performance Indicators in Decommissioning

IAEA

International Atomic Energy Agency

IAEA NUCLEAR ENERGY SERIES PUBLICATIONS

STRUCTURE OF THE IAEA NUCLEAR ENERGY SERIES

Under the terms of Articles III.A and VIII.C of its Statute, the IAEA is authorized to foster the exchange of scientific and technical information on the peaceful uses of atomic energy. The publications in the **IAEA Nuclear Energy Series** provide information in the areas of nuclear power, nuclear fuel cycle, radioactive waste management and decommissioning, and on general issues that are relevant to all of the above mentioned areas. The structure of the IAEA Nuclear Energy Series comprises three levels: **1 — Basic Principles and Objectives; 2 — Guides; and 3 — Technical Reports.**

The **Nuclear Energy Basic Principles** publication describes the rationale and vision for the peaceful uses of nuclear energy.

Nuclear Energy Series Objectives publications explain the expectations to be met in various areas at different stages of implementation.

Nuclear Energy Series Guides provide high level guidance on how to achieve the objectives related to the various topics and areas involving the peaceful uses of nuclear energy.

Nuclear Energy Series Technical Reports provide additional, more detailed, information on activities related to the various areas dealt with in the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series publications are coded as follows: **NG** — general; **NP** — nuclear power; **NF** — nuclear fuel; **NW** — radioactive waste management and decommissioning. In addition, the publications are available in English on the IAEA's Internet site:

http://www.iaea.org/Publications/index.html

For further information, please contact the IAEA at PO Box 100, Vienna International Centre, 1400 Vienna, Austria.

All users of the IAEA Nuclear Energy Series publications are invited to inform the IAEA of experience in their use for the purpose of ensuring that they continue to meet user needs. Information may be provided via the IAEA Internet site, by post, at the address given above, or by email to Official.Mail@iaea.org.

SELECTION AND USE OF PERFORMANCE INDICATORS IN DECOMMISSIONING

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHRAIN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA NUCLEAR ENERGY SERIES No. NW-T-2.1

SELECTION AND USE OF PERFORMANCE INDICATORS IN DECOMMISSIONING

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2011

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
July 2011
STI/PUB/1504

IAEA Library Cataloguing in Publication Data

Selection and use of performance indicators in decommissioning. — Vienna : International Atomic Energy Agency, 2011.
p. ; 29 cm. — (IAEA nuclear energy series, ISSN 1995–7807 ; no. NW- T-2.1)
STI/PUB/1504
ISBN 978–92–0–113010–5
Includes bibliographical references.

1. Nuclear facilities — Decommissioning — Management. 2. Project management. I. International Atomic Energy Agency. II. Series.

IAEAL 11–00689

FOREWORD

Performance indicators can be defined as a list of metrics that a company's managers or others responsible for a project have identified as the important variables reflecting operational or organizational performance. Indicators are useful because they point to trends and relationships in a concise way. The success of completing a decommissioning project on schedule and budget resides in the ability to define a clear end point (outcome) and to accurately determine intermediate progress and develop reliable forecasts to complete remaining tasks. Project indicators are essential tools of the project manager for monitoring the evolution of work, identifying departures from the project schedule/objectives as early as possible, and allowing for early corrective actions. Therefore, performance indicators are used to examine those aspects that are crucial to the success of the project.

This report builds on previous reports on generic aspects of organization and management for decommissioning of nuclear facilities (e.g. Technical Reports Series No. 399), and expands on strategies and techniques intended to provide immediate guidance to managers and other stakeholders, and quantifiable results to the project. It details significant components of project management, providing guidance for application to decommissioning projects. Good practices and experiences in the design, selection and use of performance indicators are provided. In this way, the report contributes to the systematic coverage by the IAEA decommissioning programme of non-technical aspects of decommissioning, which experience shows are often as decisive to the success of a decommissioning project as the technological aspects.

The IAEA officer responsible for this report was M. Laraia of the Division of Nuclear Fuel Cycle and Waste Technology.

CONTENTS

SUMMARY 1

1. INTRODUCTION 3

   1.1. Background 3
   1.2. Objective and scope 3
   1.3. Structure 4

2. PRINCIPLES 4

   2.1. Goals of the performance indicator system (principle 1) 5
   2.2. Requirements of users (principle 2) 5
   2.3. Selection of performance indicators (principle 3) 5
   2.4. Presentation of performance indicators (principle 4) 6
   2.5. Review, learn and improve (principle 5) 6

3. PROCESS FOR SETTING UP A PERFORMANCE INDICATOR SYSTEM 6

   3.1. Define roles and responsibilities 7
   3.2. Identify user requirements 8
   3.3. Decide the areas of performance to be covered 8
   3.4. Design performance indicators using project data 8
   3.5. Obtain stakeholder feedback and agreement 9
   3.6. Compile, interpret and report the performance indicators 9
   3.7. Plan and implement appropriate actions 9
   3.8. Review, learn and improve 10

4. SPECIFIC INFLUENCES ON THE SELECTION OF PERFORMANCE INDICATORS 11

   4.1. Facility related influences 11
      4.1.1. Physical nature of the facility 11
      4.1.2. Operational history of the facility 12
      4.1.3. Management of the decommissioning project 12
      4.1.4. External influences 12
   4.2. User requirements 13
      4.2.1. Identification of users of decommissioning performance indicators 13
      4.2.2. Areas of user interest 14

5. PRACTICAL GUIDANCE ON PERFORMANCE INDICATOR SELECTION 16

   5.1. Hierarchical framework 16
      5.1.1. Project delivery 17
      5.1.2. Financial performance 22
      5.1.3. Health, safety and security performance 23
      5.1.4. Environmental performance 24
      5.1.5. Socioeconomic performance 24
   5.2. Example of use of performance indicators 24
   5.3. Evaluating the adequacy of a performance indicator 27

6. CONCLUDING REMARKS 27

REFERENCES 29

ANNEX I: DESIGN AND USE OF DECOMMISSIONING PERFORMANCE INDICATORS IN MEMBER STATES 31

ANNEX II: CASE HISTORIES/EPISODES INVOLVING THE USE OF DECOMMISSIONING INDICATORS 82

CONTRIBUTORS TO DRAFTING AND REVIEW 87
STRUCTURE OF THE IAEA NUCLEAR ENERGY SERIES. 88

SUMMARY

The success of completing a decommissioning project on schedule and budget is determined by the ability to define a clear endpoint (outcome), to accurately determine intermediate progress, and develop reliable forecasts to complete remaining tasks. Performance indicators are used to examine those aspects that are crucial to this success. This information is required by and periodically reported to various stakeholders. Although the practice of nuclear decommissioning is maturing, it would benefit from optimal use of performance indicators.

Performance measurement is the ‘heart and soul’ of the performance based management process. Flowing from the organizational mission and the strategic planning process, it provides the data that will be collected, analysed, reported and ultimately, used to make sound business decisions. It directs the business function by documenting progress towards established objectives, identifying areas of both strength and weakness, and justifying budgetary expenditures.

In this report, practical advice is provided on the effective use of performance indicators to measure and report on the achievement of the goals and plans of a nuclear decommissioning project. The structure of the report takes the reader progressively through all aspects of designing, selecting and using performance indicators. A process for setting up a performance indicator system against basic principles is presented, including a discussion of each step in the process. The report also provides an expanded discussion of the most important influences on the identification and selection of performance indicators. Finally, practical guidance on the use of performance indicators in specific Member States is provided together with field experience.

1. INTRODUCTION

1.1. BACKGROUND

Successful project delivery requires the systematic application of the practice and tools of project management [1,2]. At the core is a clearly defined project scope with sufficient planning to cover all significant aspects of the project. These plans will vary in number and depth but will include topics ranging from scheduling, manpower, technology and cost estimation through to stakeholder relations. An important aspect of project implementation is to ensure that information is available to manage and understand performance against these plans. The presentation of this information will be in various forms to suit the user; performance indicators are one of the principal means of providing this information to those parties with an interest in or influence on the project—whether internal or external to the project organization.

Performance indicators have been defined as “a particular value or characteristic used to measure output or outcome” [3]. Thus, they communicate the progress of a project in a way that is meaningful to a user. The performance indicators are derived from the more detailed data collected, analysed and acted upon within the project. They should clearly and concisely point to trends and relationships that meet the needs of the users. These needs are likely to vary between projects and between the various people and organizations associated with a project.

Experience in Member States indicates that there are a number of ways in which decommissioning performance indicators can and have been used. Many of the indicators quoted in relevant literature have their origin in non-nuclear fields (see Refs [4–7]). Some decommissioning projects are relatively short so that the use of performance indicators is minimal (limited to end of project milestones). However, where such projects go awry, the lack of suitable performance indicators may have been a contributor if failings had not been detected, or not reported in a timely manner.

Nuclear decommissioning may also generate considerable interest from a wide range of stakeholders beyond the project team. The project team needs to inform these stakeholders on the purpose, plans and progress of the project, which will be greatly aided by the use of well designed performance indicators. These should:

- Demonstrate a decommissioning project’s progress towards its ultimate goals (e.g. time to site being de-licensed or to change of licence);
- Highlight progress on the achievement of important project milestones (e.g. planned and actual dates that a building is demolished);
- Present performance against budgets and anticipated outturn costs (e.g. expected costs versus original estimates);
- Measure performance against specific project plans (e.g. site manning levels);
- Report performance on relevant safety topics (e.g. lost time accident rates);
- Enable understanding of stakeholder sensitive issues (e.g. amounts of radioactive waste sent for disposal);
- Enable intercomparison between projects (e.g. cost comparisons for waste processing).

In addition, where performance is not meeting plans, the planned corrective actions and their implications should be suitably presented.

1.2. OBJECTIVE AND SCOPE

The objective of this report is to provide practical advice on the effective use of performance indicators to measure and report on the achievement of the goals and plans of a nuclear decommissioning project. While the advice is primarily for the use of the decommissioning project manager, its value will also be in improving the project information provided to stakeholders such as regulators and other interested groups. This report has been written with a particular aim of also providing those managing smaller, less complex facilities with a framework in which to design and implement effective performance indicators.

This report covers performance indicators that may be used to measure decommissioning performance at nuclear facilities (e.g. reactors and fuel cycle plants) and at those non-nuclear facilities that have radiologically contaminated areas (e.g. laboratories or hospitals). It does not seek to cover the off-site management of wastes from decommissioning projects nor the uranium mining industry.

1.3. STRUCTURE

The structure of the report takes the reader progressively through all aspects of designing, selecting and using performance indicators in the decommissioning of nuclear and related facilities. Following the introductory material within Section 1, the main text of this report is organized as described below.

The basic principles for selecting and applying performance indicators are presented and discussed in Section 2. A process for setting up a performance indicator system based on these principles is presented in Section 3, including a discussion of each step in the process. Section 4 provides an expanded discussion of the most important influences on the selection of performance indicators: Section 4.1 covers those influences related to the facility itself and Section 4.2 covers those related to stakeholders and other users of the information.

Practical guidance on the selection of performance indicators is provided in Section 5, to be read together with field experience, which is accessible through the reference list. Section 5.1 recommends, defines and advises on the use of a hierarchical framework. The advantages, disadvantages and use of a small set of performance indicators are presented in Section 5.2 in order to illustrate the earlier discussions. Section 5.3 provides some guidance on evaluating the adequacy of selected performance indicators. Finally, Section 6 presents some brief concluding remarks.

Two sets of annexes are provided. Annex I consists of relevant experience of the use of performance indicators in specific Member States. Annex II provides some brief but relevant case histories including the lessons drawn from them.

2. PRINCIPLES

While the monitoring and managing of performance is a major aspect of conducting a successful decommissioning project, it must nevertheless be integrated with other essentials such as clarity of scope, quality of planning and effectiveness of stakeholder management. An effective performance indicator system will need to meet certain principles, whether applied in nuclear decommissioning or elsewhere.

There follows a proposed set of principles that would support the successful establishment and use of a system of performance indicators. These principles are expressed in generic form and then each is discussed in a decommissioning project context in Sections 2.1 to 2.5:

- Principle 1: The goals of the performance indicators system should be clearly stated and these should support the achievement of overall project goals.
- Principle 2: The requirements of the users of performance indicators should be identified, understood and built into the structure and selection of performance indicators.
- Principle 3: Selected performance indicators should reproducibly measure relevant attributes in a clear, timely and efficient manner.
- Principle 4: The presentation of performance indicators should enhance user understanding of project performance and aid prediction of future performance.
- Principle 5: Arrangements should be in place to enable improvements in the performance indicator system.

2.1. GOALS OF THE PERFORMANCE INDICATOR SYSTEM (PRINCIPLE 1)

A decommissioning project will have a defined scope whose delivery should contribute to the achievement of the goals of the decommissioning programme. For example, the aim may be to safely decontaminate and demolish a building on a site, within a given budget and by a particular time. A clear statement of the project goals will aid the definition of performance indicators to measure progress towards, and achievement of, these goals. The project manager requires this same clarity from his or her client in order that he or she can design a project whose implementation will deliver these goals. The goals of the performance indicator system should be specifically stated and justified. If there is ambiguity, then the performance indicators may misrepresent progress. For example, if the building decontamination standard is not well defined, then there is a risk that work could be reported as complete (in terms of surface areas decontaminated) only for regulatory action to demand further decontamination to a higher standard.

Performance indicators must also recognize any additional specific interests of stakeholders and other users. It is conceivable that where goals differ on apparently similar projects, the appropriate set of performance indicators may also differ, particularly where there are differences in project scope, stakeholders and their interests.

The performance indicator system is likely to be largely concerned with establishing progress on the delivery of project goals or on measuring the effects of the project (e.g. in terms of radiation dose uptake). There will be detailed plans for the undertaking of the decommissioning work, which will be used as the basis for the derivation of many performance indicators. There should also be plans for other aspects (such as radiation dose uptake) so that they are also amenable to quantitative assessment through performance indicators. When plans are being met as measured by performance indicators, then all is probably well; otherwise, corrective actions may be necessary. Indicators that suggest something is potentially going to go wrong are potentially more valuable than those that reveal something has gone wrong. For example, monitoring the rate of surface decontamination is more useful in project management than whether a ‘decontamination complete’ milestone has been met. However, the simplicity of the latter may be more appropriate for some users.

2.2. REQUIREMENTS OF USERS (PRINCIPLE 2)

The potential users of the performance indicator system will vary depending on the project and its context. At a minimum, there will be the project management team, its management and its regulators. There will usually also be other internal and external project stakeholders who will need to be kept informed so as to ensure that the project receives their acceptance or active support, as appropriate.

In order to adequately inform the stakeholders, they need to be identified, all their relevant interests catalogued, and the performance indicator system designed to effectively and economically meet their needs. Some stakeholders may have strong opinions on the information they wish to receive; others may not. What may satisfy a stakeholder in one country may not satisfy the equivalent in another. Furthermore, a performance indicator on a particular topic that adequately meets the need of one stakeholder (e.g. a regulator) may not be appropriate for another (non-technical) stakeholder because of the specialist knowledge needed to fully comprehend the indicator’s meaning. The project manager must ensure that the performance indicator system takes such issues into account.

2.3. SELECTION OF PERFORMANCE INDICATORS (PRINCIPLE 3)

This principle states that “selected performance indicators should reproducibly measure relevant attributes in a clear, timely and efficient manner”. It is important that a minimum set of performance indicators are produced that meet each user’s needs, because their collection and analysis will not be cost free and because too much uncoordinated and irrelevant data can be confusing. Thus, the clarity of user requirements will inform the selection process.

Performance indicator selection will inevitably be influenced by the availability of data. An important attribute may not be directly measurable, but a small set of performance indicators may allow a useful inference of the situation related to that attribute. This is particularly the case with subjective measures such as safety culture. (See Ref. [8] with respect to how this has been handled for safety performance indicators.) Often, data will be copious and the converse temptation to generate too many performance indicators needs to be resisted, instead focusing on those which are apt, comprehensible and offer most value in terms of usable information per collection cost. A related issue is the need to avoid duplication and seek independence. In fact, a degree of compromise will be needed to ensure that the set of performance indicators is sufficient yet concise. A hierarchical approach [8] can help the project manager to achieve completeness and demonstrate the underlying logic used (see Section 5.1).

The reported current value of a performance indicator may require action by the project manager or another user. For these actions to be timely, the performance indicator seen by the user needs to be reasonably indicative of the current or very recent state of the project. Finally, the likely reaction to a performance indicator needs to be anticipated to ensure that inappropriate or perverse responses are not encouraged by the selection of less important attributes over more important ones.

2.4. PRESENTATION OF PERFORMANCE INDICATORS (PRINCIPLE 4)

Performance indicators need to be presented in a manner that maximizes user understanding. What is presented should be clear and unambiguous, as should the implications of deviation from norms and targets. Trending and pictorial techniques can aid reader understanding, especially when the information is relatively unfamiliar. Benchmarking against other decommissioning projects can be considered to build stakeholder confidence in project performance.

Good presentation requires clear procedures for the definition, calculation and reporting of performance indicators. The definition of a performance indicator may be adjusted to assist its calculation and presentation.

2.5. REVIEW, LEARN AND IMPROVE (PRINCIPLE 5)

A performance indicator system will be enhanced if it is subject to a review, learn and improve process. The initial stage could be in the form of a pilot exercise within the project before the performance indicators are rolled out to stakeholders. Regular reviews should be performed to confirm the continued validity and relevance both of individual performance indicators and of the overall performance indicators system. This is particularly important in the event of significant changes in project scope or implementation plans or in the first decommissioning project being performed. Feedback from users is also likely to be helpful in achieving continuous improvement.

3. PROCESS FOR SETTING UP A PERFORMANCE INDICATOR SYSTEM

This section presents a structured process that could be used to guide the setting up and use of decommissioning performance indicators. The process is based on good practices identified in Member States and is illustrated in Fig. 1. It also takes into account other IAEA publications relating to performance indicators [1, 3–4, 8–10].

The process aims to provide practical guidance to the organization responsible for undertaking decommissioning. Generally, this is the decommissioning project team, but it could also cover the site licensee if a separate entity. The process may involve other stakeholders, but it needs to be owned by the decommissioning organization as generator and primary user of the indicators.

The process will apply to decommissioning projects of any complexity, on facilities having any hazard or size. However, it has been designed to be proportionate to ensure that it produces a performance indicator system that is fit for purpose. Application of the process to simple, low hazard decommissioning projects should lead to a small set of straightforward performance indicators requiring simple interpretation. This is dealt with by initially establishing the roles of those responsible, the requirements of users and the areas of performance to be covered.

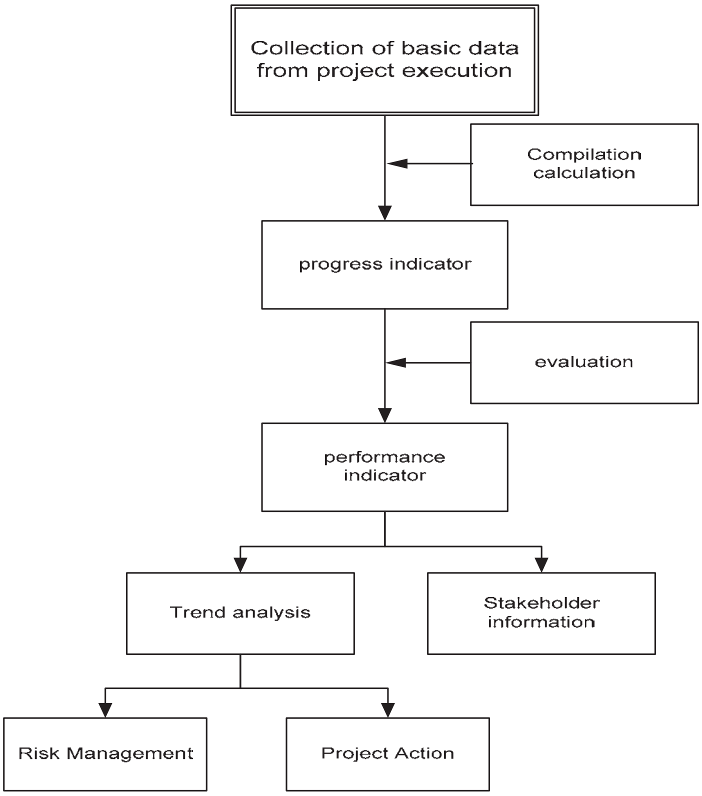


FIG. 1. Process diagram for decommissioning performance indicators.

After these steps, the scale of the subsequent work to set up and use the decommissioning performance indicators will be more clearly apparent.

Each of the main steps of the process shown in Fig. 1 is considered in turn.

3.1. DEFINE ROLES AND RESPONSIBILITIES

The primary responsibility of a decommissioning project manager is the effective management of the project. Information will be needed by the project manager to perform this role, and therefore the primary responsibility for the design and implementation of the performance indicators system lies with the project manager. The project manager needs to provide a reporting system that meets the requirements of a client [11] and is based on detailed data from within the project, assembles it into useful information and distributes it for action within the project. The project manager is also typically the primary point of contact for internal and external stakeholders. Since the reputation of the project and of the project manager's performance will be dependent on the perceptions of those who receive project information, the project manager must have a thorough knowledge of the entire performance indicators process. The project manager must ensure that the process will deliver performance indicators and other information that is necessary, timely and accurate, and that any limitations are fully understood.

The project manager will need to appoint a project data manager to be responsible for the detailed design and implementation of the reporting process and to assure the quality of the data from which the performance indicators are derived. The project data manager will be responsible for collecting, analysing, interpreting and trending, and may have delegated responsibility for presenting the performance indicators information to senior management and stakeholders.

3.2. IDENTIFY USER REQUIREMENTS

User requirements can vary from project to project, taking into account the type and size of a facility, the scale of the project and other local conditions. The project manager should carefully evaluate the reasons behind providing information to any user. If regulators and other stakeholders are provided with information that is not consistent with their roles or interests, then this can result in distraction or unproductive communications. However, the early involvement of regulators and stakeholder groups can result in better communications and relationships.

Various project stakeholder groups may exert pressure for particular performance indicators to be tracked and trended for a given project. Stakeholder interest in the application of stringent performance indicators to site decommissioning criteria can be driven by the carryover of issues from earlier operations at a site [12].

3.3. DECIDE THE AREAS OF PERFORMANCE TO BE COVERED

The measurement and reporting of the most appropriate project performance areas will help ensure that focus is maintained on those issues of greatest importance to the success of the decommissioning project [13]. There is truth in the maxim: 'what gets measured gets done'.

A typical nuclear decommissioning project will require that, at a minimum, the selected performance indicators include measures of the following issues:

— Health, safety and security performance: Is the project being conducted safely, securely, and fully addressing the risks to the facility, workers and the public?
— Environmental performance: Is the project adequately managing materials, wastes, effluents and disturbances?
— Financial performance: Is there evidence that the project is being adequately planned and budgeted, and is being implemented within these constraints?
— Project delivery: Is the project proceeding in accordance with cost, schedule and other expectations?
— Socioeconomic impacts: Is there evidence that impacts and commitments are being adequately managed?

In addition, it is sensible for the project to demonstrate that compliance with all applicable laws and regulations related to the above topic areas.

3.4. DESIGN PERFORMANCE INDICATORS USING PROJECT DATA

The successful use of performance indicators relies on the availability and reliability of project data. Procedures need to be produced that define how raw data will be collected and how it will be used to calculate performance indicators. Given the challenge that many decommissioning projects face with the availability of funding or skilled human resources, the use of existing data sources can provide quick and cost effective solutions to performance measurement needs. A performance indicator may be more robust if multiple data sources have been used to validate results. Trends are also useful as indicators of progress or change even where there is doubt over the accuracy of the absolute value of an indicator (see Case Nos 1 and 4 in Annex II). Due account should be taken that data collection and elaboration for producing a given performance indicator should not become unreasonably work and time consuming, and should be measured against the benefits accrued by the performance indicator.

The project manager should consider the use of a pilot exercise to test the adequacy of performance indicators before wider dissemination. Care should be taken to thoroughly understand the limitations of the data before a decision is taken to transmit performance indicators to a user. An asset of a good performance indicator is its simplicity in capturing performance related to a potentially complex matter, which may be undermined if the performance indicator is accompanied by caveats over applicability and accuracy.

3.5. OBTAIN STAKEHOLDER FEEDBACK AND AGREEMENT

The generators and primary users of decommissioning project performance indicators will be the decommissioning organization itself. Subsets of these performance indicators should also meet the reasonable interests and requirements of other users. Having successfully piloted the planned set of performance indicators, the project manager will need to advise project stakeholders of the performance indicators that will be made available to them, including when and in what form. This should include a demonstration that the suggested performance indicators adequately meet that user's requirements.

An agreement between an external stakeholder and the project can be formalized in a memorandum of understanding (MOU). The MOU would define the service that the stakeholder will receive from the project and the communication routes for discussion of the information provided. In order to fully satisfy a stakeholder, it may be necessary to supply data that have commercial or security sensitivity. The MOU should therefore define how such data will be safeguarded and to what uses it may be put. However, the aim should be for the project to define performance indicators that will not require such restrictions, although this may require a degree of concession by the stakeholder.

3.6. COMPILE, INTERPRET AND REPORT THE PERFORMANCE INDICATORS

The way the performance indicators will be used needs to be considered in order to determine the best form of presentation and reporting. This may differ from user to user to reflect their interests and expertise in handling the information.

As a general rule, pictorial aids will enhance user understanding of the underlying messages from the values of the performance indicators. These may include graphs to highlight trends, or colour to highlight the current value of performance indicators value versus the planned value. These pictorial aids can be represented in a form similar to the dashboard of a car to provide breadth of understanding in a concise manner [13, 14].

The dashboard is a way of allowing those running an organization or project to visualize all the elements necessary for project success, and the interactions between them. Some allow detection of changes in inter-relationships and permit incremental updating, with warning signals displayed; most are now software based. Mapping and matching stakeholders' needs with the appropriate framework is critical. Colour coding and symbols may be used to show current performance and trends. For example, green could mean ahead of target, yellow at or close to target, with red indicating unacceptable performance. Arrows or other devices could also indicate whether performance was rising or falling, even if the base colour had not recently changed. Modern computer systems are easily adaptable to such presentations and examples are apparent in reporting in many domains (e.g. Refs [13,15]).

Consideration should be given to the optimum reporting medium. For example, where certain information is targeted at particular stakeholders, direct mailing (paper based or electronic) would be most appropriate. Information can be provided in a less targeted manner by placing it on the Internet, either on a site or company web site and/or by links from local newspapers or local authority web sites (e.g. Refs [16, 17]).

3.7. PLAN AND IMPLEMENT APPROPRIATE ACTIONS

The collection and reporting of performance indicators should be geared to a specific purpose. In some cases, the user interest will be simply a desire to be informed and reassured on the general situation with respect to a decommissioning project. Other users will wish to use the information to support their own activities, e.g. project progress and expenditures may form a part of onward reporting at a higher level in an organization or to a customer [11]. Those more directly involved in the project such as the project team, and perhaps the regulators, should use the performance indicators to directly assist them in managing or overseeing the project. Current values, trends and implications should be reviewed to define appropriate actions as needed (see also Case Nos 4 and 5 in Annex II) in order to:

— Seek greater understanding of the cause of a performance indicator’s deviation or unexpected condition;
— Confirm that a performance indicator’s deviation is a function of the project, and not a facet of the performance indicator being inappropriately defined, measured or calculated;
— Put in place corrective measures and monitor the results;
— Revise project plans so that they adequately reflect current knowledge;
— Replicate any good practices that could be usefully adopted in other areas of the project or other areas of work within the responsibility of the user;
— Explain to stakeholders the implications of the performance indicators and any actions, in order to demonstrate the overall effective management of the project and to forestall stakeholder interventions that could unnecessarily affect project delivery.

3.8. REVIEW, LEARN AND IMPROVE

The foregoing discussion focused on using performance indicators to review, learn and improve (RLI) the undertaking of the decommissioning project. Although the bulleted actions do include some that encourage critical examination of the performance indicators themselves, these are basically being instigated by a deviation in project outcomes away from the plans on which the project was based. Therefore, if there were no deviations, then there would be no such performance indicator reviews. As a project advances, experience may show that some performance indicators are of little use, and thus should be eliminated.

The performance indicators system is an important part of the management of the decommissioning project and it should also be subject to regular review in order to learn lessons and improve its effectiveness for users. This may be in terms of better reflecting users’ interests, measuring important data more directly, better analysis or clearer presentation and reporting, i.e. re-examining each step in the process in Fig. 1.

As discussed above, the regular review of the decommissioning project will, as a by-product, provide an opportunity to consider the adequacy of the performance indicators system. However, opportunities can also be found on a regular basis to step back and reexamine the performance indicators system. Reporting will generally be conducted at regular intervals:

— Monthly, for prompt confirmation of project progress and actions;
— Quarterly, to update forecasts of anticipated usage of annual budgets;
— Annually, to report the outcomes of financial and safety parameters;
— Following project milestone achievements, particularly completion.

Each of these could provide an opportunity to conduct an RLI process on the performance indicator system. A note of caution is needed. One of the great benefits of some performance indicators is their ability to be trended. If they are constantly being redefined, an apparent trend may reflect the redefinition rather than the decommissioning project, and care will be needed to ensure that like is being compared with like. Where possible, this problem should be addressed by re-evaluating historical data when an indicator definition is changed. (See Case Nos 4 and 5 in Annex II.)

Where an organization is conducting (or regulating) several decommissioning projects, it will probably prefer to monitor the same performance indicators across all of their projects. If the performance indicator system is redesigned on one project, then this may limit useful benchmarking across the breadth of projects. A word of caution is of note when using the same performance indicator across several projects: the significance of a particular performance indicator may vary from project to project; the same value for a performance indicator in two projects may correspond to different levels of performance in the two projects.

4. SPECIFIC INFLUENCES ON THE SELECTION OF PERFORMANCE INDICATORS

A variety of factors might influence the performance indicators selected for a site or a facility undergoing decommissioning. Some of these factors may be based on plant attributes (e.g. the size of facility, the facility type and facility ownership). Others may be based on management attributes or desires (e.g. the needs of various stakeholders, demands of internal and external priorities). Some projects may have the need to address unique factors applicable to their specific situation. These factors will need to be considered as well those described here. Additionally, certain factors, and therefore performance indicators, may evolve over time and become more critical for project success at some particular stage during decommissioning. This can determine which performance indicators are monitored at which stage in the project.

The remainder of Section 4 describes the most widely applicable of these factors. Generally, these are related to facets of the facility and its decommissioning (Section 4.1), or of stakeholders (Section 4.2).

4.1. FACILITY RELATED INFLUENCES

Various facility or project related influences may have a bearing on the selection of the decommissioning performance indicators. These are related to:

— The physical nature of the facility (Section 4.1.1);
— Its operational history (Section 4.1.2);
— The management of the decommissioning project at the facility (Section 4.1.3);
— External influences (Section 4.1.4).

Although intended to be a helpful prompt for the project manager, the above cannot be considered comprehensive, and others may be of greater importance on particular projects.

4.1.1. Physical nature of the facility

— Type of facility: The challenge of decommissioning simpler facilities (such as those found in hospitals) will be less demanding than more complex ones (such as a fuel reprocessing plant). The performance indicators selected should be proportionate to the complexity faced. Where a project manager is aware of the performance indicators reported on a similar type of facility, they provide a starting point for his or her project.
— Size of facility: Larger facilities, such as a power generating reactor facility, may warrant having a larger number of more detailed performance indicators. A smaller facility, such as a university laboratory, is only likely to require a small set of straightforward performance indicators.
— Single or multiple facility sites: When several facilities are located on a common site, they may be of different types and at different stages of their lives. Some may be operating, while others are shutdown or undergoing decommissioning. The way a site is managed will influence the performance indicators used. It is likely that certain requirements will be placed on all facilities on the site to support consistent aggregated off-site reporting. As such, some performance indicators may be required that would not be normally necessary on a single facility site undergoing decommissioning.
— Facility hazard: Performance indicators should demonstrate the progress in reducing the hazard at a facility as decommissioning goes forward. In addition to the radiological hazard, chemical and other industrial hazards will also need to be considered. The performance indicators should be proportionate to the facility hazard.

4.1.2. Operational history of the facility

- Age of facility: Older facilities may pose more of decommissioning challenge. This can be due to the loss of original drawings or operational records, outmoded operational practices and perhaps a period of neglect after final shutdown. Consequently, stakeholders may pay closer attention and a greater number of performance indicators will be needed to demonstrate that the situation is under control.
- Stage of decommissioning: There will be some differences in performance indicator requirements at different stages of the decommissioning of a facility. Immediately after final shutdown, evidence of planning and characterization of hazards will be the priority tasks. During dismantling, the waste arisings and their management will be of particular interest. The critical area during a period of deferment will be evidence that a robust surveillance and maintenance regime is safeguarding the facility condition. At the time of site clearance, validity and progress of the final site survey will be predominant. Nevertheless, issues such as cost, staffing and events will require reporting throughout decommissioning.
- Abnormal events: The greater the frequency and severity of such events (in operation or decommissioning), the greater the decommissioning challenge. Moreover, a site with a history of abnormal events is likely to have raised generated significant stakeholder concerns, which will be reflected in demands for information during decommissioning. (see Case No. 3 in Annex II.)

4.1.3. Management of the decommissioning project

- Project controls: The project team will require a set of tools and techniques to plan the project and to monitor and manage its implementation. They will include the gathering of data and other measurements of progress. A subset of this information can form the basis of performance indicators, which, unlike the project controls, are intended to be also for consumption outside the project.
- Programme management: A project may be a part of a larger programme of related or co-funded projects, on one or more sites. Performance indicators at the programme level will be built up, at least partially, from those at the individual project level. This will constrain the performance indicators that are selected for tracking on the individual project.
- Key performance indicators (KPIs): These are a subset of performance indicators that projects may highlight to monitor their performance against the project baseline. Typically, these include among other factors: project delivery, production rates, health, safety and security performance, environmental performance and project staffing. (See also Section 5.2 where an illustrative set of such indicators is discussed in more detail.)
- Use of performance indicators to trigger incentives: Certain performance indicators may form the basis of incentive arrangements written into staff or commercial contracts. There has been extensive experience of this practice in the United States and elsewhere, including decommissioning work at both commercial and government facilities [18]. Care is needed to ensure that the attribute being measured by the performance indicator with incentives is critical to the success of the project; otherwise unwanted or perverse behaviours may be encouraged. With respect to this issue, Ref. [19] notes that “the behaviour and activities of directors, managers and leaders at all levels should include ensuring that any reward systems promote the control of risk and accident prevention, recognize safe behaviour and challenge unsafe behaviour”. Furthermore, unexpected conditions can be encountered as decommissioning work progresses, which may require a change in direction; inflexibility in the contract provisions related to performance measurement could lead to take a non-optimal approach, at least temporarily.

4.1.4. External influences

- State of development of a country’s nuclear industry: Some countries have substantial experience in managing nuclear facilities in general, and decommissioning in particular. Consequently, experience may have allowed to establish reporting norms so that the selection of many performance indicators would be determined by custom and practice. In some cases, this development may establish the requirement from regulatory authorities that certain performance indicators are tracked as a mandatory part of decommissioning.

— Benchmarking: Certain performance indicators might be selected for tracking and trending to allow unambiguous comparison of performance between similar facilities, both domestically and internationally. For example, if a reactor is being decommissioned, performance indicators might be selected that have been used previously in the decommissioning of relevant reactors elsewhere.
— Meeting reporting standards: A project may be required to comply with certain reporting requirements to its corporate management, as a condition of membership of industry or trade groups, or of organizations such as the IAEA or the World Association of Nuclear Operators (WANO).
— Stakeholder requirements: the issue of meeting stakeholder requirements is the subject of Section 4.2.

4.2. USER REQUIREMENTS

This section provides guidance on the identification of decommissioning project performance indicator users and their likely areas of interest. Although these matters must be derived specifically for each decommissioning project, there are some general themes likely to apply to many decommissioning project situations.

4.2.1. Identification of users of decommissioning performance indicators

A number of performance indicator users are identified below, although it should be recognized that in a particular situation, not all may be present, some organizations may fulfill more than one role and there may be additional stakeholders unique to a site or project. Nevertheless, the listed users are likely to provide good coverage in most situations and therefore a basis for project specific activities.

— Regulators — covering all legal and regulatory requirements. Regulators involved with the decommissioning of a facility generally include radiological and non-radiological health and safety, environmental authorities as well as security and transport. In some countries, more than one of these roles may be performed by the same body. In addition, local authorities may be responsible for regulating planning issues and post-decommissioning site uses. All potential regulatory interfaces should be identified and accounted for early in the project planning and reporting processes. The regulators may have established their own approach to measuring licensee's performance [13, 20], which would need to be built into the performance indicator system.
— Project team — is directly engaged in the active delivery of the decommissioning project.
— Facility licensee—has legal responsibility for the nuclear licensed site and for all works executed on it, including decommissioning. The licensee will often be the same organization as the project team, but this need not be true.
— Facility owners — hold title to the facility or site, although may not be actively engaged in work on-site. They will often act as the customer of the project team, but their level of involvement may vary from one situation to another. If a facility owner is neither the decommissioning project manager nor the licensee of the facility, then its predominant interest may be financial — not only in terms of the company financial health, but also the socioeconomic effect around the facility. The latter is particularly likely to be the case if the facility is owned by government or another public body. An example of an owner that is not a licensee is the UK's Nuclear Decommissioning Authority; its interests and measures are defined in its business plan [21], its reporting procedure [11], and its brief monthly programme updates [15].
— Senior management of the owner, licensee and/or project team — is the entity accountable for work carried out by or for their organizations at the executive or board level. Further, the term 'senior management' indicates the organizational level to which the project, licensee or owner management report. In general, senior management wish to see that the commitments made to them by their staff are being met and, if not, then what the implications are, including the effects of any planned corrective actions. Performance of a given decommissioning project will probably be only one facet of the corporate overview that senior management is seeking. Decommissioning project performance indicators may therefore need to be adapted to meet the wider corporate requirements [22, 23].

— Contractors — are outside parties engaged by the project team to assist in the delivery of the project. In decommissioning projects, large amounts of work may be contracted to external contractors. The role and number of contractors can be significant, and their interactions with the licensee must be managed by the project team, resulting in a high interest in the performance indicators on finance and project delivery. In their working areas, the contractors must fulfill the legal and regulatory requirements.
— International bodies — are organizations such as the IAEA, the OECD/Nuclear Energy Agency (OECD/NEA) and the European Union. International organizations, institutions or groups of people may affect a decommissioning project through financing, mandatory conventions or standards, the availability of expertise or information exchange, and/or research and development.
— Non-governmental organizations (NGOs) — are often special interest or pressure groups. Some pressure groups may have a high interest in the project before the implementation and seek influence through licensing procedures that include public participation.
— Other countries — are neighbours of the state in which the project is sited and who may feel affected by it.
— Fund providers — are a source of funding for the project. A funding entity is any organization or authority that plays a role in providing funding for decommissioning, e.g. government, companies, shareholders and ratepayers. Regular reporting on the financial situation of the project will be required.
— Local communities — include local authorities, elected officials and influential individuals in the area of the facility.
— Government — includes the relevant national or regional level authorities.
— Trade unions — represent the site workforce.
— General public — includes interested individuals within the wider community.

Note that the media (e.g. internet, television, newspapers and journalists) are not separately included because they are considered a vehicle for the dissemination of information on — or a challenge to — a project, rather than as having a direct interest in it. There may be other stakeholders (e.g. other nuclear industry operators, educational institutions, pro-nuclear lobby groups, etc.) that are not explicitly included here, but the principles discussed below can also be directly applied to them. Decommissioning project stakeholders and their management are covered in depth in Ref. [24].

4.2.2. Areas of user interest

The users of performance indicators listed above will have interests that range from the specific to the general and from a detailed and sustained interest to no more than an occasional awareness. In some cases, apparently diverse users will share an interest in the same topic, but the nature of the interest will be different. This will provide a challenge in reporting at the right level for both.

During implementation of a nuclear decommissioning project, in addition to the obvious safety, engineering and project issues, there are other non-technical aspects to be managed. Decommissioning projects often have social, economic or political dimensions, especially where the facility being decommissioned has had a major economic impact on an area. External stakeholders may find these dimensions as important or more so than technical matters, and the project team will need to address them in order to achieve a positive project outcome.

To aid further discussion, the potential areas of interest can be grouped under the following project areas:

— Health, safety and security — to protect workers and the public against the facility and project hazards;
— Environmental impact — to protect the environment (on- and off-site);
— Financial — to manage the funds provided to conduct the project;
— Project delivery — to deliver the specified project scope to time and cost;
— Socio-economic — to meet expectations and commitments to facility personnel and to the local community.

Note that the topic of legal and regulatory compliance is not explicitly listed because meeting the above project objectives in these project areas will implicitly include meeting any relevant legal or regulatory requirements. Other objectives could be identified, but this set is a usable minimum. For example, quality is not listed because it could affect the achievement and the accuracy of all of those identified above and can therefore be treated as an enabler rather than an objective.

The matrix in Table 1 aims to provide a more detailed indication of the likely level of interest of each user in each area of interest. Whereas stakeholders and their interests will inevitably vary from one decommissioning project to another, it is possible to make some generic predictions of interest.

The suggested level of interest has been assigned at four levels: high, medium, low and negligible interest illustrated with the use of the colours shown in the legend. To re-emphasize, this assignment is not prescriptive since it is likely to vary between projects as well as during a project's lifetime and in response to any notable events.

Some broad conclusions can be drawn from an examination of Table 1. Users involved in site management and project delivery have medium to high interests across most topic areas. The names used in Table 1 may cover a range of stakeholders. For example, although environmental impact is shown as being of great interest to regulators, this is dominated by the specialist environmental regulator.

Where strong user interest is indicated, it is likely that a number of performance indicators will be necessary to satisfy them. Where there is limited interest, and particularly where there is negligible interest, it will usually be of little value to provide such information. However, there may be some resistance to this, which will require discussion, and preferably, an agreed resolution. An example from Table 1 will illustrate its meaning. The matrix shows that local communities have high interest in the aspects of the decommissioning project with local impacts, i.e. safety, environment and socioeconomics. Their interest in project delivery will likely be limited to how long the project is forecast to continue. The local effects of finance and regulatory compliance will be very limited, which is reflected in the low interest shown.

TABLE 1. USER INTEREST IN PERFORMANCE INDICATOR TOPIC AREAS

	Health safety and security	Environmental impact	Financial	Project delivery	Socioeconomic
Regulators					
Project team					
Facility licensee					
Owners of facility					
Senior management					
Contractors					
International bodies					
NGOs					
Other countries					
Fund providers					
Local communities					
Government					
Trade unions					
General public					

Legend

	High interest		Low interest
	Medium interest		Negligible interest

Facility owners and senior management have common areas of interest throughout the duration of the project, reflecting their high level accountabilities to shareholders or the government. They will probably be satisfied with quarterly reporting reflecting their distance from day-to-day work. The providers of decommissioning funds do not generally have wide interests, with reporting requirements limited to specific responsibilities. The government may be a fund provider, but it also has provided a regulatory framework and may be affected by public reaction should serious problems arise at the facility. Thus, it has wider interests, albeit at a low level unless things go badly.

The interest of neighbouring countries is usually highest before project implementation, as in the European Union, where an approval is required before decommissioning can commence. This reflects concerns that actions in one country can affect another. NGOs, particularly anti-nuclear pressure groups, are likely to show the highest interest in the areas environment; health, safety and security. Finally, trade unions will focus on the interests of their members, particularly safety and the socioeconomic impact of decommissioning.

The information made available to each type of stakeholder must be sufficient to meet their potential interests yet limited to essentials to aid their usage. In effect, the closer a stakeholder is to the project, the greater the detail they are likely to seek, at least in some topic areas. Performance indicators are the most effective way to concisely and clearly transmit most of this information. The data used to calculate most performance indicators will be derived by the project team, supplemented by the site operator or licensee as appropriate. The specific needs of stakeholders may require the combination or redefinition of data or performance indicators in order to identify KPIs of particular value in establishing the project status — the aim being to report performance in a simple, clear and reliable manner.

5. PRACTICAL GUIDANCE ON PERFORMANCE INDICATOR SELECTION

This section provides practical guidance on the selection of performance indicators. The guidance in this section is based on three main sources of information:

— Experience in the Member States, e.g. as described in material presented in Annex I of this report;
— IAEA reports relating to safety performance indicators (SPIs) [8–10];
— Experience of those who have contributed to the drafting of this report.

The quoted IAEA publications [8–10] emphasize that there is a significant advantage in the use of a hierarchical framework to define areas to be covered. Once these areas have been identified, performance indicators then need to be selected that provide adequate representation of these areas. Consequently, this section adopts a hierarchical framework with a three level approach. Examples of performance indicators are provided for each of the areas in the hierarchical framework.

The list of areas is indicative rather than exhaustive — performance indicators must be targeted at the specific decommissioning project. Furthermore, not all areas will apply to all decommissioning projects. For example, if the project deals with a low hazard facility, then fewer safety or environmental performance indicators are necessary. Applying considerations such as these should enable the identification of the most appropriate areas for a particular project. It is emphasized that this discussion is related to performance indicators that are primarily designed for use outside the project team.

5.1. HIERARCHICAL FRAMEWORK

Figure 2 shows a three level hierarchical framework along the lines proposed elsewhere [8]. Note that for the sake of clarity, only ‘Health, Safety and Security Performance’ has been developed to level 2, and only ‘Worker

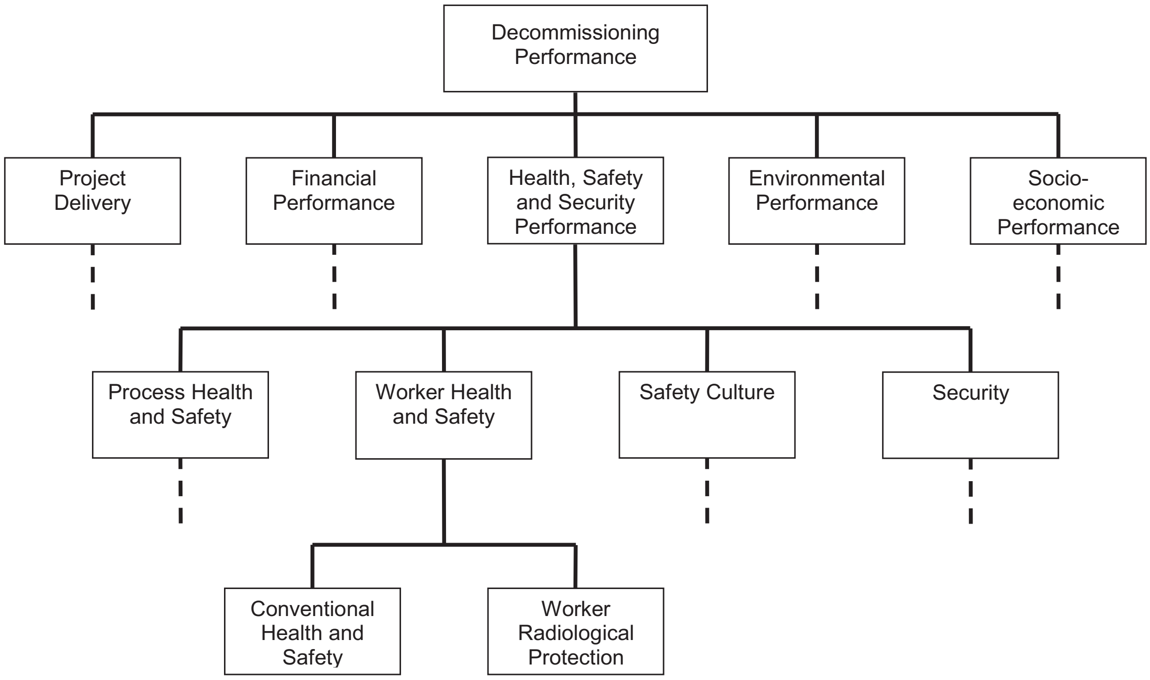


FIG. 2. Hierarchical framework for defining decommissioning performance indicators.

Health and Safety' has been developed to level 3. At some projects, performance indicators may be sufficiently defined by level 2 so that there is no need to proceed to level 3.

Level 1 has been derived using the concept of key performance questions (KPQs) introduced by the Advanced Performance Institute [25]. It is defined by the following five KPQs (consistent with the topic areas listed in Section 4.2.2, but with some reordering for the purposes of presentation in Fig. 2):

(1) Is project delivery adequate? — 'Project Delivery'
(2) Is financial performance adequate? — 'Financial Performance'
(3) Is health, safety and security performance adequate? — 'Health, Safety and Security Performance'
(4) Is environmental performance adequate? —'Environmental Performance'
(5) Is the socioeconomic performance adequate? —'Socioeconomic Performance'.

The above items at level 1 are briefly discussed in turn in the following sections, which refer to Tables 2 to 6 [29–41], respectively, where a typical hierarchy is detailed across all three levels. The reader can consult Tables 2 to 6 for examples of performance indicators in these areas. This could be by using the example performance indicators directly or by creating a similar but more appropriate locally defined indicator.

Tables 2 to 6 include a number of references to easily available examples of the use of similar performance indicators in practice. These references are usually placed together with the example performance indicators, in column 3. However, some are placed in the 'Level 2' column, which apply to all their associated examples. More examples can be found in the material presented in Annex I, which have been added in appropriate places to the tables. It should be noted that greater detail may often not be freely published due to commercial or other constraints.

5.1.1. Project delivery

Whereas all the performance indicators within the Fig. 2 hierarchy will be relevant, 'Project Delivery' focuses on demonstrating that the project is capable of achieving the required scope to an acceptable quality through the use of a competent team and with risks well managed (see Table 2).

TABLE 2. PROJECT DELIVERY PERFORMANCE INDICATORS

Level 1: Project Delivery		
Level 2	Level 3	Example of performance indicators
Implementation of plans	Project schedule [17, 29]	Milestones met
		Estimated date of completion
		Availability of site for reuse
	Backlog	Number of corrective maintenances overdue
	Quality	Amount of rework
Project progress	Achievements by area [30, 31] (Annex 1D)	Fuel stored/shipped versus plan
		Waste produced versus plan
		Waste stored, cleared, disposed
		Buildings decontaminated/demolished
		Suspect land remediated (%)
	Reduction in hazardous areas	% of site in higher hazard zones
Project risk management	Schedule constraints	Number of long lead items
		Number of critical path items
	Quantitative risk management	Estimate of technical and budget uncertainty
		Contingency level
	Stakeholder risks	Estimate of stakeholder satisfaction
	Regulatory risks	Licenses/approvals outstanding as % of total required (Annex 1C)
	Contract risks	Amount of equipment and resource to be provided by external organizations
Labour	Staffing [13, 17]	Total employed (full-time equivalent)
		% subcontractors
		Skill/professional requirements
	Competency	% of roles and responsibilities defined
		Training by topic area (Annex 1D)
		% training sessions attended

An overall indicator for project success could be a comparison of the completed activities versus the baseline schedule. Further detail could examine the percentage of work completed (by systems and/or rooms) and the number of planned milestones achieved on time. The physical outputs of the project should also be included in the scope of the indicators, for example, the quantity of decommissioning materials dismantled, collected, conditioned, recycled, packed, stored or disposed of — all compared to planned values.

Particular attention should be paid to interdependencies between activities because the potential delay of one activity may lead to delay in any dependent ones. Separate indicators should be developed in such cases to monitor the critical path of the project.

If external contractors are involved in the project, their performance should be subject to assessment both by using their own specialist set of indicators and by suitable indicators designed for this purpose by the project team (see also Section 4.1.3).

Poor performance on compliance with regulations can severely impact the progress and overall success of a decommissioning project. It is prudent to self-assess on such matters so that deficiencies can be detected and resolved at an early stage before any regulatory action. This can also build the confidence of the regulator in the

TABLE 3. FINANCIAL PERFORMANCE INDICATORS

Level 1: Financial Performance		
Level 2	Level 3	Example of performance indicators
Liability fund management	Adequacy of fund	% of project cost provided in fund
		% decommissioning fund used
		Actual vs. planned liability discharged
	Risk management of fund	% contingency remaining
Project financial management	Budget conformance [29]	Planned versus actual expenditure
		Rate of spending in remainder of year
		% risk monies used [13]
	Adequacy of budget [11]	Future budget estimates versus plan
		Savings made
		Income generated
		Cost of financing
	Sources of costs	Actual versus plan for each area, e.g. waste, dismantling and staffing
Commercial	Incentives to project	Performance targets [17]
	Incentives to subcontractors	Performance targets [17]
Value management	Earned value measures [11, 17, 29] Cost Performance Index	
		Schedule Performance Index
		Estimate at completion

TABLE 4. HEALTH, SAFETY AND SECURITY PERFORMANCE INDICATORS

Level 1: Health, Safety and Security Performance		
Level 2	Level 3	Example of performance indicators
Process health and safety	Hazard reduction	Safety and environmental detriment [32]
		Progress vs. significant hazard reduction milestones (Annex 1E)
	Incidents	Number of nuclear and radiological events recorded
		Number of nuclear and radiological events reported to the regulator (Annex 1E)
		Technical quality of incident and allegation activities [33]
		Accident investigations conducted [34]
		INES events (level 1 and above) [17, 35]
		Number of fire brigade actions

TABLE 4. HEALTH, SAFETY AND SECURITY PERFORMANCE INDICATORS (cont.)

Level 1: Health, Safety and Security Performance		
Level 2	Level 3	Example of performance indicators
	Plant condition	Number of safety defects not corrected within the site's own target time (usually 24 hours) in the month (Annex 1E)
		Total number of plant defects (Annex 1E)
		Number of corrective work orders issued for safety systems [8]
		Number of modifications not physically started within 12 months of modification receiving approval (Annex 1E)
		Number of modifications not closed 12 months after the completion of physical work (Annex 1E)
	Challenges to safety systems	Number of breaches of conditions and limits necessary in the interests of safety (Operating Rules) (Annex 1E)
		Number of fire events
	Safety plant out of service	Number of safety plant items out of service
		Number of failures in safety systems [8]
		% availability of safety plant
		Revealed and unrevealed failures of safety plant
		Safety system functional failures [36]
		Cooling water systems [36]
	Emergency preparedness [37]	% of adequate emergency exercises completed in the year to date (Annex 1E)
		Findings during emergency drills/exercises [8]
		Drill/exercise performance [36]
		Emergency response organization drill participation [36]
		Alert and notification system reliability [36]
	Public radiological protection	Maximum dose at the site boundary
		% of approved limit
		Average dose at the site boundary
		Radiological effluent technical specifications/offsite dose calculation manual [36]
Worker health and safety	Conventional health and safety [29, 34, 35] (Annex 1D)	U.S. Occupational Safety and Health Administration (OSHA) days away case rate
		OSHA total recordable incidents rate
		Time since last lost time accident [17]
	Worker radiological protection [17, 35] (Annex 1E)	Collective dose against plan (Annex 1D)
		Average individual dose (contractors and employees)
		Maximum individual dose (contractors and employees)
		Number of contamination events
		Number of internal contaminations
		Outcome doses as % of ALARA budgets
		Occupational exposure control effectiveness [36]

TABLE 4. HEALTH, SAFETY AND SECURITY PERFORMANCE INDICATORS (cont.)

Level 1: Health, Safety and Security Performance		
Level 2	Level 3	Example of performance indicators
Safety culture	Attitude to safety	Number of breaches of safety procedures
		% of corrective actions overdue (Annex 1E)
		% of adverse behavioural observations
		% of events due to human error [8]
		% of events due to training deficiencies [8]
		Number of temporary modifications [8]
		Number of findings in configuration management [8]
		Percentage of core competency posts vacant (Annex 1E)
	Striving for improvement	The number of investigation reports not issued within six weeks of the event (Annex 1E)
		Number of independent internal safety and QA inspections and audits [8]
		Number of findings from internal safety and QA inspections and audits [8]
		Average time to clear findings from safety and QA inspections and audits [8]
		Number of similar or repeated deviations and failures [8]
	Leadership and management	% of nominated managers on track with their safety interactions (Annex 1E)
		Number of items remaining on senior manager’s watch lists (Annex 1E)
Security	Physical protection [36]	Not provided “to ensure that potentially useful information is not provided to a potential adversary” [36]

TABLE 5. ENVIRONMENTAL PERFORMANCE INDICATORS

Level 1: Environmental Performance		
Level 2	Level 3	Example of performance indicators
Environmental management	Implementation of environment plan	No. of targets achieved (%)
		Maintenance of accreditation achieved (e.g. [38])
Waste and material management	Incidents	Pollution incidents: Annual number of category 1 and category 2 incidents [39]
		Breaches of permits: Annual number of category 1 and category 2 breaches of permits [39]
	Radioactive	Clearance of material (tonnes and % of total dismantled)
		Waste generated requiring disposal (tonnes and % of total dismantled)
		The percentage of intermediate level waste that has been packaged and conditioned according to regulators’ guidance [39]

TABLE 5. ENVIRONMENTAL PERFORMANCE INDICATORS (cont.)

Level 1: Environmental Performance		
Level 2	Level 3	Example of performance indicators
	Non-radioactive	Clearance of material (tonnes and % of total dismantled)
		Waste generated requiring disposal (tonnes and % of total dismantled)
		Hazardous waste (tonnes and % of total dismantled)
Effluent management	Radioactive	Airborne emissions: Bq and % of limits [39]
		Liquid emissions: Bq and % of limits
		Annual liquid alpha discharges: Bq and % of limits [39]
		Annual liquid beta/gamma discharges: Bq and % of limits (excluding tritium) [39]
		Annual liquid tritium discharges: Bq and % of limits [39]
		Annual technetium-99 discharges from reprocessing Bq and % of limits [39]
		Critical group doses due to discharges (retrospective assessment): mSv and % of limits [39]
	Non-radioactive	Airborne emissions: amounts and % of limits
		Liquid emissions: amounts and % of limits
		Discharges of nitrates and nitrites to controlled waters: amounts and % of limits [39]
Disturbance management	Consumption	Total natural resources used
		Utility electricity consumed per groundwater volume treated [40]
		Water usage (excluding cooling water) [39]
		Energy consumption [39]
		Quantity metal recycled [17]
		Quantity paper recycled [17]
	Activity related	Noise levels
		Traffic levels
		Dust levels
		Greenhouse gases on and off-site, including transport [39]
	Ecosystem	Species population measures

strength of project systems and processes. Suitably designed performance indicators can be used to communicate compliance performance, not only to regulators, but also to staff and other stakeholders, thereby reassuring them about the adequacy of control of the project. Such indicators include the number of regulatory permissions requested versus those received and the total number of days of delay incurred due to regulatory interface issues (the target being zero).

5.1.2. Financial performance

Funds need to be provided to allow decommissioning to take place. The decommissioning project team must manage them carefully so as to ensure that the project can be completed as has been committed to the fund provider. Thus, effective project accounting is vital to the successful delivery of decommissioning projects. The project

TABLE 6. SOCIOECONOMIC PERFORMANCE INDICATORS

Level 1: Socio-Economic Performance		
Level 2	Level 3	Example of performance indicators
Stakeholder engagement	Meetings [41]	% attendance of own personnel at regular scheduled meetings
		% questions raised compared to 1st meeting
		% unplanned to planned meetings
	Resources [41]	% person-hours spent in relation to total management
		Funding level of socio-economic team
		Funding to support new businesses
		Funding of community projects
Local economy	Employment impacts [41]	% employment of original staff
		% employment change after project start
		Value of resources used contracted versus resources in house
		% local personnel employed
		% tax income change in local community
Future site use	Non-nuclear use of site	Investment on site in new enterprises/ year
		New companies registered on site
	Nuclear use of site	Date of proposed transfer for reuse
		Value of site to new owner

accountant needs to be able to support the project team by providing financial data so as to allow the team and its stakeholders to understand the true financial state of the project (see Table 3).

The financial performance indicators used often only look back at what has occurred. Analysis of performance indicators based on trending and comparison of planned and actual values, for example, of expenditure, does allow diagnosis of deviations from plan, prediction of the future position and corrective actions. Experience has shown that the use of earned value analysis [26] can provide more sophisticated indicators, although the effort to set up a full earned value system may not be economic on smaller projects.[1]

5.1.3. Health, safety and security performance

Health, safety and security indicators are typically ‘lagging’ (outcome) indicators because they present outcomes *after* the event, revealing how the project has performed, for example, the number of lost time accidents in the past year. They do not actually indicate the likelihood of future unwanted events, but only monitor trends.

Leading indicators aim to identify in advance a deviation on a matter of limited immediate impact, but which could be indicative of weaknesses that may later lead to more serious events or performance. An example might be the percentage of planned safety training courses actually attended by staff. In this case, a low value may indicate resource shortages or poor safety motivation that could lead to more lost time accidents in the future. However, effective leading indicators are more difficult to design than lagging ones. Table 4 presents both leading and lagging performance indicators.

Some of the more useful leading indicators of a general degradation in safety are often associated with safety culture; the IAEA has produced several publications in this field [27]. Over and above its insights are later remarks

[1] Earned value analysis (EVA) is an industry standard way to: (a) measure a project progress, (b) forecast its completion date and final cost, and (c) provide schedule and budget variances along the way. EVA integrates all three elements. It compares the planned amount of work with what has actually been completed, in order to determine if *cost, schedule and work accomplished* are progressing as planned.

made by the Chairman of the US Nuclear Regulatory Commission (NRC) on the NRC Perspective on Safety Culture [28].

5.1.4. Environmental performance

The treatment of environmental impact (or environmental safety) is similar to that of health, safety and security, except that it looks predominantly at the impact of the project off-site (see Table 5), e.g. noise, disruption and emissions. Normally, an environmental impact assessment (EIA) must be conducted as part of the licensing and approval process of a decommissioning project. This should provide guidance on the priority areas for monitoring and measurement during the project and thereby aid the formulation of apt performance indicators.

5.1.5. Socioeconomic performance

The progress of a decommissioning project may be influenced by the attitudes of the local and wider community. Measures will be needed of the success of the project in managing these relationships. A stakeholder management plan should be in place that will offer the most effective source of relevant indicators. Although this is an area particularly dependent on local characteristics, performance indicators may cover topics such as (Table 6):

- What is working and what is not in any active public relations programme. The site’s own nominated spokesperson could be a source of data, but site stakeholder groups or general public attitudes could be surveyed;
- What commitments have been given on how the site will interact socioeconomically with the outside world, e.g. proportion of worked placed locally or amounts spent on locally supplied services;
- General supporting data that may be useful in discussions. e.g. numbers of contractors versus staff employed in various phases of the project.

5.2. EXAMPLE OF USE OF PERFORMANCE INDICATORS

The sections below emphasize that the performance indicators used on a particular decommissioning project will be dependent on a number of factors. In this section, 12 typical performance indicators are discussed in more detail in order to illustrate typical issues. These issues include the need for clear definition; the relevant topic area; likely interested parties in the matter covered by the indicator; and clarity over what sort of deviation from a target would be regarded as negative, and what positive. The example of performance indicators to be discussed are listed below and numbered as KPI 1 to KPI 12. KPI is an acronym for key performance indicator, defined as “a short list of metrics that a company’s managers have identified as the most important variables reflecting operational or organizational performance” [4]:

- KPI 1 Project milestone forecasts and achievements;
- KPI 2 Number of outstanding licensing issues;
- KPI 3 Percentage of decommissioning funds used;
- KPI 4 Rate of planned expenditure during remainder of financial year;
- KPI 5 Manpower costs;
- KPI 6 Percentage of staff and contractors sourced locally;
- KPI 7 Amount of radioactive waste produced;
- KPI 8 Proportion of decommissioning materials reused or recycled;
- KPI 9 Quantities of aerial and liquid radioactive discharges;
- KPI 10 Radioactive doses received by workers;
- KPI 11 Number of procedural non-compliances;
- KPI 12 Measured stakeholder satisfaction.

The KPIs are discussed in the context of a non-specific decommissioning project.

The most obvious measure of success in the delivery of a decommissioning project is whether critical items in the plans are achieved on schedule (KPI 1). These ‘milestones’ may well have incentives associated with them, particularly where the owner has let a contract to another organization for overall management of the decommissioning project [15, 29]. They need to be clearly defined and critical to project success. An example might be the clearance of a formerly contaminated building that allows its demolition. If this milestone occurs other than at the planned date, then it is likely to have implications on later milestones, including project completion, as well as other issues such as cost, funding and other resource requirements. Due to its fundamental nature of KPI 1, it is likely to be of interest to a wide range of stakeholders.

There are many reasons for a delay in achieving a milestone. The most troubling ones may be those that at first seem to be beyond the immediate control of the project team such as a late clearance of licensing issues or hold points by a regulator. Consequently, the project manager and the regulator will likely wish to measure the number of common licensing issues and when they are due (KPI 2). KPI 2 would then indicate any delays in obtaining regulatory authorizations and the need of regulatory agreements not taken into account in the original project, etc. Again, a clear definition is important since both parties need to be working towards the same goals.

Whatever the causes of delay (or acceleration), there are likely to be financial effects. The project manager and the decommissioning funds provider will wish to monitor the usage of these funds against the plan (KPI 3). The funds at the disposal of the project manager are usually strictly limited, although some contingency funds may be available on application and after justification. In order that the fund holders may manage their affairs, they need good notice of changes; KPI 3 together with revised forecasts can help. There are a range of techniques to assist in this, such as earned value analysis [26]. However, a simpler approach will be sufficient for many projects, since the primary aim is visibility and thus avoid surprises.

For many projects, funds will not be provided for their full length but only for a defined period, such as a financial year. In such cases, the project manager will have a budget earmarked to deliver the agreed milestones in that year, but which may not be automatically available in the following year should there be underspending due to delays. One important issue that can arise here is a belief within the project that delays in work (and spending) early in the year can be recovered later in the year. This can lead to situations where the predicted rate of expenditure rises steadily through the year, eventually reaching unrealistic levels. Awareness of this threat can be raised by the use of KPI 4 [29] — again, helping to reduce the chance of unpleasant surprises for the fund provider.

Decommissioning costs arise from various sources. One important element will be the cost of manpower (KPI 5), which would estimate the departure from estimated manpower or unexpectedly high salaries/wages. At the end of facility operations, this will occur at the operational level; one of the aims of decommissioning is usually to reduce this, as the hazard managed on the facility is reduced. However, not only will some existing skills be required well into the decommissioning project, but also new ones. Part of the planning activity will be to smooth the call for these skills to avoid skilled manpower from being released and later rehired, and to avoid their underemployment for substantial periods of time.

The effectiveness of manpower planning will be important for the effective management of decommissioning as a whole, and KPI 5 needs to be designed to reflect this. A deviation in KPIs is likely to indicate wider issues in the delivery of the underlying decommissioning plans. Accordingly, it will be of reasonably wide interest to stakeholders, not only in terms of project progress, but also socioeconomically in the implications for continued employment of staff. As a result, it is likely that KPI 5 will be expressed for external use in non-financial terms such as numbers of people employed or total person-hours per period.

A socio-economically interesting extension of KPI 5 is the question as to what part of the workforce (staff and/or contractors) are from the local area (KPI 6). This element would measure actual vs. planned participation of local workforce. It is not unusual for commitments to be given to trade unions and local community representatives in order to maximize the employment of local people or companies [41]. Thus, KPI 6 would indicate to these stakeholders the extent to which that commitment was being met.

Having discussed the financial and human resources necessary to decommission, this report will now focus on project activities themselves. The aim of a decommissioning project is generally to manage and remove radiological and other hazards so as to release the facility or site for a nominated future use. Radiological hazard is what is special about the nuclear and other facilities covered by this report. Thus, the major by-products of decommissioning are radioactive wastes. Many of the stakeholders of the project would be interested in a measure of the wastes produced in decommissioning, which is what KPI 7 would seek to measure. However, this is not a simple measure [30, 31].

The management of radioactive waste in decommissioning covers several stages, for example: production, processing, storage, packaging and dispatch for disposal. Furthermore, there will be choices in how each of these stages is approached, and different stakeholders may have different preferences. For example, some potential radioactive waste may be capable of chemical processing that would reduce the mass and volume sent for disposal, but may increase chemical hazards to workers and liquid discharges to the environment.

A radioactive waste strategy should have been established as part of the facility decommissioning plans, which should be explained to stakeholders, with their agreement obtained where necessary. Thus, the project may have several related KPIs such as KPI 7, 8 and 9 above. They will need careful and precise definition and to be understood by the relevant stakeholders. The main aim of these KPIs will be to show that the radioactive waste strategy is being delivered. If a KPI deviates from the expected or planned value, it could reflect delays in project progress, a radiological source term differing from that assumed in the plans, or the effect of a change in strategy and its implementation. On such stakeholder sensitive topics, the project manager needs to be proactive in dealing with the impact of such deviations. In particular, the value of some KPIs may be limited by law (e.g. aerial discharge limits) and regulatory action may be prompted as such a KPI approaches limits.

Another important consequence of the radiological inventory is the radiation dose received by workers (KPI 10); this KPI is also not straightforward [17, 35]. At an operating facility, the lower the value of KPI 10, the better, since some radiation dose is usually an inevitable consequence of operation of the facility. However, once a facility is shut down, annual doses can be minimized by simply avoiding placing people in the plant, although decommissioning requires human interaction with the plant, often in a more intrusive and prolonged way than in operation. Indeed, doses can be higher in decommissioning than in operation. Thus, the primary issue is ensuring that doses are kept as low as reasonably achievable (ALARA).

Measuring the success of ALARA procedures is more challenging than simply adding up dose. Completing a task with a radiation dose well below budget may be a sign that the estimation process was flawed rather than that the work was performed well. Stakeholders, especially regulators, will expect to see a justified dose budget set for the project; KPI 10 is used to show whether this is being achieved in practice. As with other KPIs, this measure will be sensitive to changes in schedule and source term, as well as project performance. Project managers will have to be proactive in managing reactions to deviations in such a safety sensitive topic.

Radiological hazards are not the only safety challenges in decommissioning. In most facilities, the greatest risk of serious health and safety consequences are likely to be from those faced in any demolition task: asbestos, electricity, chemicals, slips, trips and falls. Outcome (or ‘lagging’) indicators such as KPI 10 can be derived for any hazard (e.g. number of lost time accidents per year). A challenge for the project manager is to try to define meaningful indicators that are more ‘leading’ in their nature. In some cases, actual accidents (or lost time, etc.) may be compared against accident statistics in the non-nuclear construction/demolitions industries. As discussed in Section 5.1.3, such indicators would act as measures of the underlying safety culture with the aim of giving early warning of deterioration in safety culture that could lead to later unwanted events. One possibility is KPI 11, measuring procedural non-compliance.

Safe decommissioning requires that a set of validated procedures are used to carry out potentially hazardous tasks. Although not all unwanted events arise due to procedural non-compliances, they are implicated in many. Workers should be encouraged to report where the procedure was not followed and the reasons for it. This feedback can be added to the results of audits, behavioural safety observations and post-event analysis to construct KPI 11. In this case, the goal is achieve a KPI value of zero — as long as this is not being achieved through underreporting. KPI 11 is likely to be of most value within the project organization, but the site licensee (if different) and the regulator are also likely to be interested [8].

The final KPI example is that of a measurement of stakeholder satisfaction (KPI 12). This KPI will inevitably be somewhat subjective in nature. It can be derived by surveying relevant stakeholders [24]. Although subjective, some quantitative or semi-quantitative values can be obtained by designing surveys with some form of scoring included. This increases the value of the KPI as changes in the value of KPI 12 will probably be more meaningful than the absolute value. In some cases, the stakeholder may also agree to the project manager providing a view on the strength of the relationship from the project’s perspective.

It should again be stressed that the performance indicators or KPIs discussed above are only typical of what will be needed on a decommissioning project, but the issues described related to use of the example KPIs chosen are likely to apply to many others.

5.3. EVALUATING THE ADEQUACY OF A PERFORMANCE INDICATOR

Having selected an intended performance indicator it is important to consider whether its validity will be sufficiently assure to allow it do the communication role it has been selected for. This section provides some guidance on this.

Performance indicators can be evaluated either qualitatively or quantitatively [9]. In terms of qualitative evaluation, it has been proposed [9] that a performance indicator that meets the following criteria may be regarded as adequate:

(1) The performance indicator is adequate for the decommissioning organization.
(2) The associated data cannot be easily manipulated.
(3) The necessary data are available or can be obtained. If they cannot be easily obtained, they can be considered in this category if the information that the performance indicator provides is very important.

In terms of quantitative evaluation, it has been proposed [9] that performance indicators are evaluated against seven criteria:

(1) Face validity — how well the performance indicator represents the area;
(2) Data availability;
(3) Data quality;
(4) Manipulability;
(5) Workload;
(6) Amenability to goal setting;
(7) Positive or negative measure.

One Member State proposed [42] that a performance system and the performance indicators that support it should be:

- Relevant to what the organization is aiming to achieve;
- Able to avoid perverse incentives in order not to encourage unwanted or wasteful behaviour;
- Attributable — the activity measured must be capable of being influenced by actions that can be attributed to the organization, and it should be clear where accountability lies;
- Well-defined with a clear, unambiguous definition so that data will be collected consistently and the measure will be easy to understand and use;
- Timely, producing data frequently enough to track progress and quickly enough for the data to still be useful;
- Reliable — accurate enough for its intended use, and responsive to change;
- Comparable with either past periods or similar programmes elsewhere;
- Verifiable, with clear documentation supporting it, so that the processes which produce the measure can be validated.

6. CONCLUDING REMARKS

A decommissioning project will only meet its declared objectives — and be seen to be doing so — if it is monitored in such a way that those involved in the project, and their stakeholders, can easily understand the process. The selection and reporting of the correct performance indicators, in terms of coverage and validity, will enhance this understanding.

Ideally, a range of performance indicators will be chosen, because this will allow the project to be viewed from different perspectives. This also dilutes any tendency for indicators to drive perverse behaviour since a project required to meet a range of performance targets will only be successful if performing strongly across the range. For example, if the monitoring of a project is almost entirely conducted based on financial measures, then safety and quality may suffer (what gets measured gets done).

The performance indicators received by any external stakeholder or other user should be the minimum number consistent with ensuring user understanding. Effective and imaginative presentation of performance indicators will increase understanding and their value to the project and its stakeholders.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization and Management for Decommissioning of Large Nuclear Facilities, Technical Reports Series No. 399, IAEA, Vienna (2000).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Planning, Managing and Organizing the Decommissioning of Nuclear Facilities: Lessons Learned, IAEA-TECDOC-1394, IAEA, Vienna (2004).

[3] Balanced Scorecard Institute, Definitions of General Management Terms: http://www.balancedscorecard.org/Definitions/tabid/145/Default.aspx.

[4] ROYAL SOCIETY FOR THE PREVENTION OF ACCIDENTS, DASH — Director Action on Safety and Health Measuring and Reporting on Corporate Health and Safety Performance, http://www.rospa.com/occupationalsafety/dash/measuringOS&H.htm.

[5] UK HEALTH AND SAFETY EXECUTIVE, A Guide to Measuring Health & Safety Performance, HSE, London (2001), http://www.hse.gov.uk/opsunit/perfmeas.pdf (accessed on 16 Feb. 2010).

[6] ALARCON, L.F., GRILLO, A., FREIRE J., DIETHELM, S., “Learning from collaborative benchmarking in the construction industry”, Proc. 9th Annual Conf. Intl. Group for Lean Construction, Singapore, 6–8 Aug. 2001, http://cic.vtt.fi/lean/singapore/Alarconet.pdf.

[7] UK Department of the Environment, Transport and the Regions, KPI Report for the Minister for Construction, London (2000), http://www.berr.gov.uk/files/file16441.pdf (accessed on 16 Feb. 2010).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, IAEA-TECDOC-1141, IAEA, Vienna (2000).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Development and Implementation of Safety Performance Indicators for Nuclear Power Plants, Safety Reports Series, IAEA, Vienna (2010).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Development of Nuclear Power Plant Safety Performance Indicators for Use by a Regulatory Body, IAEA Safety Reports Series, IAEA, Vienna (2010).

[11] NUCLEAR DECOMMISSIONING AUTHORITY, Baseline Management System — Performance Reporting and Reviews, Doc. No. PCP13 Rev. 1, NDA, Cumbria (2007), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=9257.

[12] OHIO ENVIRONMENTAL PROTECTION AGENCY, Fernald Cleanup Fact Sheet, December 2007, http://www.epa.state.oh.us/swdo/divisions/FFS/Fernald/FernaldSiteInfo/FernaldCleanupFactsheet.aspx.

[13] ENERGY FACILITY CONTRACTORS GROUP, DOE Performance Metrics Reporting Process Point Paper Revision 2, EFCOG Nov. (2002), http://www.efcog.org/wg/ism/Pefrormance_Metrics_Info/DOE-PM%20Point%20Paper.pdf.

[14] UNITED STATES DEPARTMENT OF ENERGY, Energy Facility Contractors Group Performance Metric Manual Rev. 1, U.S. DOE, Washington DC (2002), http://www.efcog.org/library/publications/Performance%20Metric%20Manual.pdf.

[15] NUCLEAR DECOMMISSIONING AUTHORITY, Programme Update — Sep. (2009), http://www.nda.gov.uk/sites/updates/programme-update-sept-2009.cfm.

[16] NUCLEAR DECOMMISSIONING AUTHORITY, Value Framework, 25 Feb. (2008), http://www.nda.gov.uk/stakeholders/newsletter/value-framework.cfm.

[17] DOUNREAY SITE RESTORATION LIMITED, Site clean-up performance report for Nov. (2009), http://www.dounreay.com/UserFiles/File/Performance%20Reports/Nov%2009%2020%20PR-NPSUP2009%20Nov%20B.pdf.

[18] Fluor Fernald Inc., Fernald Closure Project, Project Management Institute 2007 Project of the Year Submittal, http://www.pmi.org/PDF/Fernald%20Project%20of%20the%20Year%20Nomination.pdf.

[19] UK HEALTH AND SAFETY EXECUTIVE, Safety Assessment Principles for Nuclear Facilities 2006 Edition, Revision 1 HSE London (2008), http://www.hse.gov.uk/nuclear/saps/saps2006.pdf (accessed on 16 Feb. 2010)

[20] UNITED STATES NUCLEAR REGULATORY COMMISSION, Guidance for Performance-based Regulation, NRC, Washington, DC (2002), http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0303/br0303.pdf (accessed on 16 Feb. 2010).

[21] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Business Plan 2009-12, NDA, Cumbria (2009), http://www.nda.gov.uk/loader.cfm?csModule=security/getfile&pageid=28874.

[22] UNITED STATES DEPARTMENT OF ENERGY, Audit Report on Environmental Management Performance Measures, US DOE, Washington DC (2002), http://www.ig.energy.gov/documents/CalendarYear2002/ig-0561.pdf.

[23] BAUER. K, The Power of Metrics: The CPM Dashboard: The Framework, the Power of Metrics, Information Management Magazine, Apr (2004), http://www.information-management.com/issues/20040401/1000940-1.html.

[24] INTERNATIONAL ATOMIC ENERGY AGENCY, An Overview of Stakeholder Involvement in Decommissioning, IAEA Nuclear Energy Series No. NW-T-2.5, IAEA, Vienna (2000).

[25] ADVANCED PERFORMANCE INSTITUTE, What Are Key Performance Questions? API/BWMC Ltd, Milton Keynes, UK (2008),
http://www.ap-institute.com/downloads/080129%20What%20are%20KPQs%20(2).pdf.

[26] MEREDITH, J.R., MANTEL, S.J., Jr., Project Management — A Managerial Approach, Wiley, New York (2000).

[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Developing Safety Culture In Nuclear Activities — Practical Suggestions to Assist Progress, Safety Reports Series No. 11, IAEA, Vienna (1998).

[28] MESERVE, R.A., Safety Culture: an NRC Perspective, INPO CEO Conference, Atlanta, Georgia (2002),
http://www.nrc.gov/reading-rm/doc-collections/commission/speeches/2002/s-02-033.html (accessed on 16 Feb. 2010).

[29] WASHINGTON CLOSURE HANFORD, River corridor Closure Project monthly Report, Nov. (2009),
http://www.washingtonclosure.com/news/docs/reports/empr/2009/RCCrpt-nov09.pdf (accessed on 16 Feb. 2010).

[30] ENERGY FACILITY CONTRACTORS GROUP, Performance Metrics Manual, WSRC-RP-2002-00252 (2002), http://www.efcog.org/wg/ism/Pefrormance_Metrics_Info/Performance%20Metric%20Manual.pdf.

[31] MENSER P., It's a big job — INL's Idaho Cleanup Project is not for the meek, Post Register, Idaho (2008),
http://www.postregister.com/special/siteofimpact/story.php?accession=1001-02032008.

[32] NUCLEAR DECOMMISSIONING AUTHORITY, NDA Prioritization Procedure, Doc. No. EGPR02 Rev. 4, NDA, Cumbria (2008), http://www.nda.gov.uk/documents/upload/EGPR02-NDA-Prioritisation-Procedure-Rev4.pdf (accessed on 16 Feb. 2010).

[33] UNITED STATES NUCLEAR REGULATORY COMMISSION, Reviewing the Common Performance Indicator, Technical Quality of Incident and Allegation Activities, Procedure No. SA-105, US NRC, Washington DC (2007),
http://nrc-stp.ornl.gov/procedures/sa105.pdf.

[34] CHUNG, D.Y., TAFT, R.A., MCEAHERN, P.M., Application of Integrated Safety Management in Decommissioning Activities: Ensuring the Safety of Workers Throughout the Changing Environment of Decommissioning, Lessons Learned From the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities (Proc. Conf. Athens, 2006), IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PubDetails.asp?pubId=7739.

[35] NUCLEAR DECOMMISSIONING AUTHORITY, NDA Annual Health, Safety, Security and Environment Report 2007–2008, NDA, Cumbria (2008), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=21886 (accessed on 16 Feb. 2010).

[36] UNITED STATES NUCLEAR REGULATORY COMMISSION, Inspection Procedures & Performance Indicators by ROP Cornerstone, NRC, Washington, DC (2008), http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/cornerstone.html.

[37] UK Health and Safety Executive, Performance Indicators for the Assessment of Emergency Preparedness in Major Accident Hazards, prepared for the Health & Safety Executive, Contract Research Report 345/2001, HSE London (2001), http://www.hse.gov.uk/research/crr_pdf/2001/crr01345.pdf.

[38] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Environmental management systems — Requirements with guidance for use, ISO 14001 (2004).

[39] UK ENVIRONMENT AGENCY, Improving Environmental Performance - Sector Plan for the Nuclear Industry, Version 1, EA, London (2005), http://publications.environment-agency.gov.uk/pdf/GEHO1105BJVE-e-e.pdf?lang=_e (accessed on 16 Feb. 2010).

[40] US ENVIRONMENTAL PROTECTION AGENCY, Technology News and Trends, Issue 30, US EPA, Washington DC (2007), http://cluin.org/products/newsltrs/tnandt/0507.cfm (accessed on 16 Feb. 2010).

[41] DOUNREAY SITE RESTORATION LIMITED, Dounreay Socio Economic Plan 2009–10, Dounreay (2008), http://www.dounreay.com/page/social-responsibility/socio-economic-plan/dounreay-socio-economic-plan-and-strategy
(accessed on 16 Feb. 2010).

[42] HM Treasury (UK), Choosing the Right FABRIC — A Framework for Performance Information, Mar. (2001),
http://www.hm-treasury.gov.uk/d/229.pdf.

Annex I

DESIGN AND USE OF DECOMMISSIONING PERFORMANCE INDICATORS IN MEMBER STATES

This annex provides examples of the design and use of performance indicators in several Member States. These do not necessarily represent best practice but by consulting these examples the reader will be able to see how performance indicators have been applied in a range of real decommissioning situations. These national annexes reflect the experience of their contributors and, although consistent with the main text, are not intended as specific guidance. These annexes have only been edited to the extent considered necessary to assist the reader.

I–A. DECOMMISSIONING OF THE ASTRA-MTR RESEARCH REACTOR FACILITY (AUSTRIA): PLANNING AND EXECUTION OF THE PROJECT — PERFORMANCE INDICATORS

I–A.1. Introduction

A key part of the implementation of the project was ensuring that those involved internally and externally have the information they need to respond to evolving conditions — performance indicators are one of the principal means of providing this information (see Section 1.2).

At the time of the ASTRA-MTR research reactor decommissioning at the Seibersdorf site, Austria had no history of dismantling of nuclear facilities. The document deals with the strategy, the planning, the start and the continuous progress of the project. A suitable framework of PIs is identified as it was actually applied in the process. The structure of the accompanying reporting system is explained and results obtained in terms of schedule, materials and budget are analysed.

I–A.2. The history of the reactor

In 1958, a federal agreement was reached in Austria to construct a 10 MW MTR multi-purpose research reactor of the American Machinery and Foundry (AMF) design at a site approximately 30 km southeast of Vienna near the village of Seibersdorf. On 29 September 1960, the ASTRA reactor (Adapted Swimming Tank Reactor Austria) reached first criticality. After a period of initial operation, the average extent of operation per year since 1966 has been 500 to 900 MW·d/a.

After a referendum held in Austria in November 1978 generally rejecting the use of nuclear power in the country and preventing the already built nuclear power plant (NPP) at Zwentendorf from becoming critical, the scientific use of the reactor subsequently decreased. After several modifications, the commercial possibilities of the reactor were extended. Nevertheless, the income of the reactor by commercial use hardly exceeded 50% of the total operating costs of roughly EUR1,300,000 per year.

In 1997, the new management of the Austrian Research Centers, Seibersdorf (ARCS), responsible for the operation of the reactor, decided to shut down the reactor permanently at the earliest possible date due to political and financial reasons. A first deadline for the shutdown was communicated on 1 January 1998. Due to commitments and obligations to the users of the reactor and the date communicated by the U.S. Department of Energy (DOE) to accept the ASTRA's spent fuel, this deadline was extended to 1 January 1999.

I–A.3. The goals of decommissioning

Since the ASTRA reactor was the first of the three research reactors in Austria undergoing decommissioning, no particular experience and regulations in decommissioning of these facilities were available. On the other hand, throughout reactor operations, the personnel of the reactor who were directly responsible for the technical adaptations had outstanding experience in handling and cutting procedures under operating conditions and were familiar with the technical features of the reactor and the necessary safety procedures.

Between April 1998 and April 1999, a comprehensive study was prepared by ARCS on behalf of the Austrian Government as the key owner of the ARCS and the facility to provide a clear picture of the possibilities in decommissioning. The remaining operating time was partly dedicated to determine empirical data related to the activation of the pool alumina liner, the shielding concrete and other major components.

The goals for the decommissioning with reference to buildings, structures and funds were defined to:

— Remove activated and contaminated materials from the reactor;
— Keep the amount of radioactive waste to a reasonable minimum;
— Keep the costs of the decommissioning as low as possible;
— Clear and preserve the building for further unrestricted re-use.

The goals for the decommissioning with respect to people and the environment were:

— To protect the staff from unnecessary exposure (ALARA-principle);
— To apply the necessary physical surveillance to personnel and environment;
— To take appropriate measures to prevent contaminations and the spreading of contaminations;
— To protect the environment from hazards implemented by the decommissioning process.

I–A.4. Definition of the key stakeholders

Facility owner	ARCS (until March 2003) Nuclear Engineering Seibersdorf Ltd. (NES, from April 2003)
Government	represented by the Ministry of Science
Fund provider	Government, represented by the Ministry of Finance
Regulators	Government, represented by the Ministry of the Environment, under operating licence Government of Lower Austria, under decommissioning licence
Neighbouring countries	Via European Atomic Energy Community (EURATOM) according to the Art. 37 procedure
General public	Via an EIA
Project management	ARCS, Nuclear Services Division (until March 2003) Nuclear Engineering Seibersdorf Ltd. (NES, from April 2003)
Radioactive waste	NES, Radioactive Waste Management Department (RWMD)
Special materials	NES, Hot Cell Department (HZL).

I–A.5. Definition of the decommissioning strategy

Different strategies have been applied for the decommissioning of research reactors, from immediate dismantling to deferred dismantling in stages separated by a few months and up to several decades. The advantages and disadvantages were compared under ASTRA circumstances considering the key factors below.

Key factor: Radioactive inventory

Most of the radio nuclides identified for the ASTRA had half-lives up to 80 days, decaying sufficiently fast to allow immediate dismantling or half-lives of more than 50 years until a substantial reduction of dose rates was achieved.

Key factor: Available staffing and experience

Due to the experience of the reactor operators in handling and cutting procedures under operating conditions and their familiarity with the technical features of the reactor and the necessary safety procedures, personal exposure has always been at very low levels.

Key factor: Safety and environment

Since decommissioning work could be performed within the closed containment of the reactor building with ventilation, under pressure and drainage still fully in operation, sufficient safety standards could be guaranteed. During the whole decommissioning process, there was almost no possibility for a release of activity to the environment.

Based on these factors and with a maximum priority to safety and environmental compatibility, the immediate dismantling was recommended as the most viable option.

I–A.6. The estimation of costs

A table was prepared of the different tasks necessary to dismantle the ASTRA. The work was divided into legal procedures, preliminary efforts, actual undertakings, the establishment of radiological data, conditioning and documentation. In comparison to other tasks performed at the reactor under operation, work-times were estimated. All single tasks were drawn against the available manpower. An overall period for the decommissioning could be calculated.

A comprehensive catalogue of all parts of the reactor was prepared, including technical data such as materials, weight, size of contaminated surface and calculated levels of contamination or activation with a basic characterization of possible nuclides. The amount of radioactive waste and of materials with potential clearance probabilities was defined.

Contacts with other known decommissioning projects in Europe were established and estimated, and actual data were compared with the figures of the ASTRA.

I–A.7. The structure of the project

For reasons of legalization and administration the project was structured into four phases:

- Phase 0: Removal and ultimate disposal of the fuel elements, Aug. 1999 — Dec. 2000;
- Phase 1: Recovering and treating of remote handled waste (RHW), Jan. 2001 — Jan. 2003;
  Recovering and treatment of RHW from the vicinity of the core;
  Handling and conditioning of neutron exposed graphite;
  (Phase 1 conditioning work at the Hot Cell Laboratory continued until Dec. 2005);
- Phase 2: Recovering and treating of contact handled waste, Feb. 2003 — Jan. 2000;
  ‘fingerprinting’ contamination of the primary water systems;
  dismantling of the primary water systems;
  processing of contaminated and activated metals:
  ‘fingerprinting’ activation of Barite concrete;
  dismantling of the biological shield;
  radiological clearance of the surface of the concrete;
- Phase 3: Radiological clearance of the reactor building, Feb. 2005 — Dec. 2005.

I–A.8. The implementation of the project

Based on the obtained data, a clear picture of the tasks to be performed, the timetable of the project and the costs to be expected could be drawn with the following points:

- The first possible shipping date for the transfer of the 54 spent fuel elements was established with DOE in the fall of 2000. The estimated costs of €1,800,000 were to be covered by reserves designated for this purpose and accumulated over the years..
- 160 tonnes activated and contaminated materials had to be conditioned at estimated average costs of €4,000,000.

— Ninety years of staffing for dismantling including the conditioning of the intermediate and low level waste, the establishment of the necessary radiological parameters, clearance of the buildings, radiation protection measures and documentation; costs were estimated at €9,000,000.
— The work had to be performed with remaining qualified reactor staff, but with the option to use external labour when applying specialized techniques.
— The project's duration was timed for six years, not taking into account unforeseen delays arising throughout the performance of the task.

The total costs of the decommissioning were therefore estimated at €13,000,000, which covered all expenses except for the costs for the spent fuel removal.

According to Austrian legislation, the operation of nuclear facilities is under federal supervision. Tasks similar to those already performed during the operational period of the reactor, e.g. disposition of the spent fuel or modifications to the reactors internals and experiments, were therefore considered operational work and could be performed on the already established rules. The return of the spent fuel elements to DOE and the removal and conditioning of remote handled waste (RHW) on site was permitted under operational licence (phases 0 and 1).

The decommissioning of nuclear facilities is under supervision of the Federal State of Lower Austria. To continue the project (phases 2 and 3), a decommissioning licence through an EIA had to be obtained while performing the work up to phase 1. In advance of an EIA, EURATOM was informed according to Article 37 about the intentions to decommission the ASTRA.

After discussions of the implements of the comprehensive Decommissioning Study with the responsible stakeholders, the project was finally presented to Parliament in June 1999 and implemented by law. The funding of the project was granted, divided into six equal parts over 2000 to 2005. The budget was formally approved late in December 1999 by the Austrian Federal Ministry of Science. With necessary funds guaranteed and the expectation of a positive statement according to Article 37, EURATOM and by obtaining a decommissioning licence following an EIA in due course, work on the project could commence immediately in January 2000.

I–A.9. The identification of key performance indicators

The project scope, the defined decommissioning strategy, the calculated tasks and the expected costs in connection with the responsible stakeholders can be seen as a interconnected network of information drawn from the actual progress within the project. A need was the identification of materials removed at any time. Each part/component, active or inactive, had to be accounted for and documented from the dismantling procedures until the final disposition as radioactive waste or the documented release for re-use or disposal, if officially cleared.

Due to limited management resources, the reporting system had to be easy in handling on the one side, but informative enough to fulfill the needs of stakeholders at different levels as well as the needs of the regulators and experts and the staff. Therefore, a bottom up system was conceived, interconnecting the incoming data with the component identifications and the framework of the related tasks as defined during the planning. The procedure was handled flexibly, with possibilities for extensions when needed. Usually, the project was reviewed on a yearly basis.

I–A.9.1. Time scale

Within the structure of the project, progress over the time was defined via the four phases (point 7). Each of the phases was detailed into tasks with estimated working times (point 6) attached.

I–A.9.2. Materials flow

The comprehensive catalogue of parts (point 6) was providing data on a continuous basis. Interlocking this data with the list of tasks allowed for a follow up of the progress and the definition of milestones.

I–A.9.3. Cost analysis

The implemented SAP system in ARCS facilitated the necessary means. Because the budget was distributed on a constant annual basis, it was essential that, through the planning of tasks e.g. involving additional costs such as employing external contractors, the financial possibilities had to be kept in view.

I–A.10. The top-down documentation system

Top-down communication covering technical, administrative and legal matters at different levels was achieved through the following:

I–A.10.1. Decommissioning study

Before the initiation of the project, a comprehensive decommissioning study was prepared. The authorization of the project, the tasks and the legalization of the work were based on the project contents.

I–A.10.2. Reactor decommissioning meetings

During the planning stages of the project and throughout its operational phases 0 and 1, meetings with stakeholders were held regularly. The meetings were documented, decisions authorized and continuing steps agreed on. In the later stages of the project, after the granting of the decommissioning licence following the EIA, the meetings were occasionally held, usually to coordinate work within the RWMD and HZL Departments of NES.

I–A.10.3. Application for the Environmental Impact Assessment (EIA)

The decommissioning study was extended, emphasizing the further tasks to dismantle the reactor, e.g. bioshield, cooling system and clearance of the building.

I–A.10.4. Information of EURATOM according to Article 37 of the Treaty

Information contents were similar to the application for the EIA but structured to meet EURATOM preferences.

I–A.10.5. Working instructions

Since the working instructions for the reactor operation were not applicable for the work under the decommissioning licence, new working instructions had to be authorized and released. Alterations in the course of the decommissioning work were usually also included in the working instructions before application to the regulators.

I–A.10.6. Waste, clearance and release reports

Precise data were obtained while material and components were handled. Each item from the moment of disassembling to either the place in the ready conditioned barrel in the intermediate storage or the way of cleared items to reuse, recycling or disposal had to be followed at all times. The established number based overall identification system was duly extended throughout the process. Through this system, all data — e.g. in the daily journal, the probes and samples, the CAD drawings, the extensive photo documentation and the legal clarification documents — were interlocking. The documents were collected into a filing system.

I–A.10.7. Status reports

In addition to the regular reports, status reports had to be prepared on request.

I–A.10.8. Final report

After the successful clearance of the reactor building and in order to terminate the project, a final report with a description of the tasks performed was requested by the authorities. The report included a copy of the daily journal and of the Excel file on materials flow. The final report is also the key to the extensive overall documentation of the reactor under operation and during decommissioning.

I–A.10.9. Overall project documentation

Since there is no guarantee that digital copies are still usable/readable after long years of storage (for some items, 30 years and more), it was decided to collect important information and originals preferably in hard copy. To accommodate the extensive documentation from the decommissioning period as well as from the operating period of the reactor, a room on the top floor of the NES administration building was adapted, furnished with steel cabinets for long time preservation of the documents. The documentation contains:

— Complete documentation of the decommissioning process, planning, operating, evaluation;
— Monthly, quarterly and yearly reports on decommissioning;
— Technical and legal documentation on decommissioning;
— Extensive documentation on radiological clearance measurement and materials flow;
— A collection of working instructions valid for decommissioning;
— Papers, publications and books relating to decommissioning.

The documentation on the reactor operation contains:

— Detailed information on the fuel cycle and disposal over the full operating period;
— Logbooks of the reactor operating room and the radiological surveillance;
— Continuous records of exhaust air and surveillance of the surroundings;
— Operating handbook and records of continuous survey by the regulators
— Theoretical and technical information on experiments;
— A complete set of technical drawings of the reactor;
— Daily administrative communication and picture documentation during reactor operation;
— Personal documentation of the former reactor management.

I–A.11. The bottom-up reporting system

To relay information to the stakeholders on a regular basis and to gain data suitable for reviewing the project, a reporting system was initiated. As an overall indicator on project performance and project delivery, the information was based on the KPIs. The reasons were analysed for changes in the planning and consequences due to these changes and to unforeseen matters. The regular bottom-up reporting system consisted of the following:

I–A.11.1. Daily journal

Data were usually hand-written daily by project members. The main tasks performed were continuously added to an Excel table stating the date, component or task number, and task performed.

I–A.11.2. Materials flow

Basic data were provided by project members, continuously increased by the documentation of transfer to the RWMD, acting as the central facility for the collection, conditioning and intermediate storage of the country’s radioactive wastes, or the final release. Excel files were based on the component number with basic identifications of the parts, links to the original documents stemming either from the transfer to the RWMD or to the documents arising throughout the clearance procedures.

I–A.11.3. Monthly reports

Monthly reports were compiled from the daily data and the data on materials flow, and connected to the tasks and timetable. The reported tasks were linked to the personnel involved and statements on difficulties or advancement added. The report was extended to cover topical matters and included the planning of the forthcoming month. The next monthly report was based on the previous one so that current matters could be followed up. The Word file was made available to the directors of the Nuclear Services (NS), later to the executives of Nuclear Engineering Seibersdorf (NES) and to all staff members.

I–A.11.4. Quarterly reports

Compilation of the monthly reports: These reports emphasized the timetable and the current costs, and cover irregularities. The reports also covered topical matters and difficulties, and included the planning of the forthcoming period. The ensuring quarterly reports were based on the previous ones in order to follow up on matters. The Word file was made available to the directors of the NS/NES, the contents included into the obligatory quarterly reports from NS/NES to the Directors of the Board of the ARCS and the Scientific Board.

I–A.11.5. Annual reports

These are based on the monthly and quarterly reports with extensive reflections on status quo, review, statistics in reference to the KPIs, cost–development and development in personnel and planning. The distribution is similar to the quarterly reports.

I–A.11.6. Health and safety reports

A standardized monthly data collection following radiation protection was part of a general routine within all departments of the ARCS concerned with radioactivity. Additionally, personnel on the job were equipped with electronic dosimeters providing instant information. The readings of the electronic dosimeters were regularly collected on a daily basis. The daily journal covering the undertaken tasks made it possible to immediately identify tasks responsible for positive results. Official health and safety reports comparing actual and calculated values were usually prepared annually or on request.

I–A.12. Summarizing the project with respect to the performance indicators

The final goal of the project was the release of the buildings for re-use. Immediate dismantling was chosen to be the optimum decommissioning strategy. Decommissioning work started with the disposition of spent fuel. It was immediately continued with the removal of remote handled waste, followed by the removal of contact handled waste, and finalized with the decontamination of the reactor building to achieve the clearance level for unrestricted re-use. With the release of the reactor building from regulatory control, the decommissioning of the ASTRA was terminated in October 2006, approximately ten months behind schedule.

Below, an overview is provided of the development of the timescale, the materials flow and the actual costs in relationship to the performance indicators (point 9) on a task related basis.

I–A.12.1. Analysing the performance of the project with reference to the timescale

In order to cope with delays usually caused by administrative difficulties outside the competence of the decommissioning management, e.g. unexpected waiting for licences, it was decided to enforce the project team by suitable co-workers leased from an outside company and to run tasks parallel where possible, e.g. dismantling the biological shield and the primary water-systems in the independent underground pump room.

Engaging an external workforce for specialized tasks, e.g. the cutting of concrete, was already decided during the planning for decommissioning.

The preparations of the fuel transfer and the loading of the transport containers with the 54 spent fuel elements were within the projects costs (phase 0). The cost of the transfer and disposition of the spent fuel were covered by funds collected on a continuous annual rate during reactor operation. Table I–A.1 summarizes an entire ASTRA project by detailing main tasks over time.

I–A.12.2. Analysing the materials flow in relationship with the tasks

The conditioning of contact handled materials and special materials, i.e. graphite and beryllium, had to be carried out by the project staff supported by the colleagues and facilities of the Hot Cell Department in order to fulfill the acceptance criteria at the storage facility. Immediate dismantling with traces of, for example, Co-60 still present in low level activated or contaminated areas simplifies detection and clearance and assist in defining reliable radionuclide relationships.

The obligation to reduce radioactive waste has been followed ambitiously. Under Austrian conditions, there are no established routes to introduce metals into the market, although the radionuclide content is well below the clearance levels for unrestricted re-use. Such metals would have had to be considered 'radioactive' waste. Germany has established routes for the recycling of cleared metals. In cooperation with a German company licensed for the melting of these metals, 42 metric tonnes of cleared ASTRA metals were recycled for re-use. These extensive characterization efforts and the introduction of diamond wire cutting to dismantle the biological shield resulted in a considerable reduction of radioactive waste in comparison to the original planning, at 83 versus 160 tonnes. (See Table I–A.2 for more detail.)

I–A.12.3. Analysing the costs relationship with the tasks

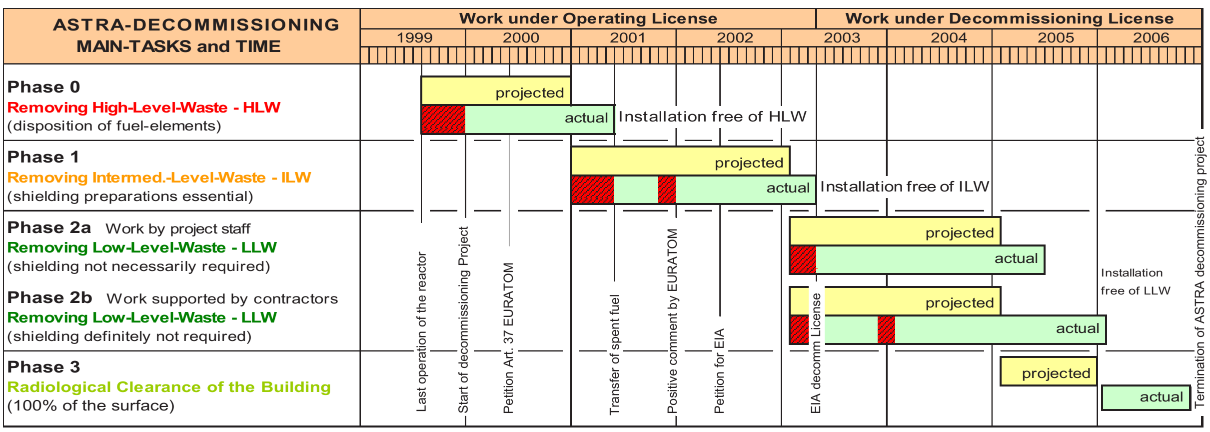
After the decision to dismantle the reactor immediately after the final shutdown, using the expertise of the reactor staff, a swift continuation of the work was essential. for economic reasons. Due to retirement, only two out of ten members of the original staff remained until the end of the project. Replacements had to be contracted.

The costs of manpower (project staff, personnel leased and specialists employed) dominate the budget with 72% of the total costs. The costs for conditioning and storage of radioactive waste amounted to 18% of the total costs.

Realistic early planning, preventing delays and flexibility in the implementation of the project were crucial. In order to keep the project within the financial limits, it was necessary to apply a continuous trade off between decontamination efforts (expenditures in terms of person-hours) versus minimization of radioactive waste (savings in storage and disposal costs).

The costs exceeding the provisions for the fuel disposition and the purchase of a whole body monitor were subject to special approval by the authorities and covered out of project funds. The money was reimbursed in 2006. Table I–A.3 highlights costs associated with the ASTRA decommissioning phases.

TABLE I–A.1. ASTRA DECOMMISSIONING — MAIN TASKS AND TIME



Note: Red bars (hatched areas) indicate times lost through delays outside the power of the project management.

TABLE I–A.2. ASTRA DECOMMISSIONING — TASKS AND WASTE MATERIALS

ASTRA-DECOMMISSIONING - TASKS and MATERIALS		Operating License		Decommissioning License		2000 to 2006	
		2000	2001 2002	2003 2004 2005	2006		
		Phase 0	Phase 1	Phase 2	Phase 3	[metr.TONS]	%
RADIOACTIVE WASTE	High. Level Waste - spent fuel (special treatment required)	1)				*)	
	Intermed. Level Waste - metals (shielding required, 5 Mosaik container)		3			3	0.1
	Low Level Waste - metals (no shielding required, 1 Konrad type 2 cont.) 2)		9			9	0.4
	Low Level Waste - graphite (no shielding required, 1 Konrad type 2)		7			7	0.3
	Low Level Waste - concrete (no shielding required, 3 Konrad type 2)			25		25	1.2
	Low Level Waste - solid unburnable (no shielding required, 200-L-drums)		34			34	1.6
	Low Level Waste - solid burnable (no shielding required, to incinerator)		5			5	0.2
	Total radioactive waste					**83**	**3.8**
INACTIVE WASTE	Waste (cleared for conventional disposal)		7	137		144	6.6
	Metals (cleared for re-use through melting process)		42			42	1.9
	Materials (cleared for unrestricted re-use)		91	1430		1521	70.1
	Materials (removed from building after clearance for re-use on site)				384	384	17.6
	Total inactive waste					**2091**	**96.2**
TOTAL AMOUNT OF WASTE	[metr. TONS]	**0**	**198**	**1592**	**384**	**2174**	
	%	0	9.1	73.3	17.6		100

TABLE I–A.3. ASTRA DECOMMISSIONING — TASKS AND COSTS

ASTRA-DECOMMISSIONING TASKS and COSTS		Operating License		Decommissioning License		2000 to 2006	
		2000	2001 2002	2003 2004 2005	2006		
		Phase 0	Phase 1	Phase 2	Phase 3	[M-EURO]	%
CATEGORY	Management, engineering, administration, documentation	0.317	0.528	0.883	0.330	**2.058**	13.5
	Characterisation, radiation protection, safety engineer	0.747	0.820	1.446	0.381	**3.394**	22.3
	Personnel (project staff and contractors)	1.078	1.287	2.611	0.512	**5.488**	36.0
	Equipment and materials procured	0.194	0.489	0.407	0.195	**1.285**	8.5
	Conditioning and intermediate storage of radioactive waste	0.568	0.518	1.011	0.694	**2.791**	18.3
	Additional funds required for fuel disposition	0.207				**0.207**	1.4
TOTAL	[M-EURO]	**3.111**	**3.642**	**6.358**	**2.112**	**15.223**	
	%	20.4	23.9	41.8	13.9		100

The estimated costs of the decommissioning project were calculated based on the price index of 1999 with a budget of €13,080 million. The money was equally distributed at a rate of €2180 million per year over the 2000–2005 period. A compensation for the annual inflation was agreed in 1999. From 2000 to 2006, the average inflation rate in Austria was 2.5% annually. (See Table I–A.4 for more details.)

To compensate for the inflation rate and to cope with unexpected delays and expenditures, another €0.673 million were approved in 2006 to finish the project. The project was finally terminated ten months later than scheduled, with an overdraft of 4.7%.

I–A.13. Conclusions

It is the role of the project management to properly plan and prepare and well in advance the decommissioning tasks at the technical, administrative and legal levels. Flexibility in coping with unforeseen difficulties or delays is another important obligation. Therefore, all technical and administrative skills necessary to plan and execute the tasks must be represented within the project to react and cope immediately with unexpected occurrences. Regular contacts and open cooperation with authorities is an asset.

TABLE I–A.4. ASTRA DECOMMISSIONING — BUDGET DEVELOPMENT OVER TIME

	ASTRA-DECOMMISSIONING - BUDGET DEVELOPMENT	2000	2001	2002	2003	2004	2005	2006	Total
BUDGET	*Project budget as estimated in 1999 (not validated)*	*2 180*	*2 180*	*2 180*	*2 180*	*2 180*	*2 180*		*13 080*
	Project budget - average annual inflation-rate of 2.5% considered [1)]	2.235	2.290	2.348	2.406	2.466	2.528		**14 273**
	Costs exceeding provisions for fuel-transfer [2)]	(due to exchange rate EURO / US$ - not foreseen in 1999)							**0.207**
	Purchase of a whole-body monitor [2)]	(further use after decommissioning - not calculated in 1999)							**0.070**
	Additional funding in 2006, necessary to finish the project [3)]	**additional expenditure + 4.7 %**						0.673	**0.673**
	Actual costs of the decommissioning of the ASTRA **[M-EURO]**								**15 223**

It is of utmost importance to continuously upgrade project data and carry out proper surveys before and during the work in order to ensure a smooth execution. Good quality of the established data is essential for quick and reliable decisions and procedures, the reduction of hazards and the minimization of waste.

Early recognition of, for example, the fatal influence of impeding delays and decisions to take counteractions by investing in clearance efforts resulted in profitably reducing radioactive waste. It also gave flexibility to cover part of the additional costs in manpower, allowing for uninterrupted continuation of the work, which tended to maintain the project’s balance.

The establishment and proper application of suitable indicators, together with the implementation of a comprehensive documentation process are reliable means to assess the project’s performance, validate the effect of measures and communicate the status of the project to staff, management and stakeholders.

I–B. PERFORMANCE INDICATORS USED FOR DECOMMISSIONING PROJECTS CARRIED OUT BY DANISH DECOMMISSIONING

I–B.1. Introduction

Danish Decommissioning (DD) is a state organization established in 2003 with the sole objective to decommission the nuclear research facilities formerly operated by Risø National Laboratory. These facilities are the only nuclear facilities in the country. Nuclear power has never been introduced, and in 1985, the Danish Parliament decided that this energy source should not be part of the national energy plans. This decision has not yet been revoked. The research facilities to be decommissioned were three reactors (2 kW, 5 MW and 10 MW), a Hot Cell facility and a small fuel fabrication workshop. Two of the reactors have been decommissioned to date and the Hot Cell facility is undergoing decommissioning. For details on the facilities and the state of decommissioning, see Ref. [I–B.1].

Following some technical problems with the largest reactor, the management of Risø National Laboratory took the decision to shut it down permanently in September 2000. In the spring of 2003, the Danish Parliament then decided that decommissioning should be initiated of all nuclear research facilities at the site. The Parliament's decision was based on, inter alia, a study carried out by Risø National Laboratory [I–B.2], where a preliminary description of the expected decommissioning work was given, together with a cost estimate of up to DKK1.2 billion. The Parliament decided that the decommissioning of all the facilities should be carried out within a period of 11–20 years and reach a greenfield end state.

DD became an institution under the Ministry of Science, Technology and Innovation, and has a staff of about 80. Most dismantling work is carried out by DD's own staff whereas, for instance, demolishing work is contracted to external companies.

I–B.2. Scope of the present description

The description below focuses on indicators showing overall performance of projects, and not the daily management of the work. It should be noted that DD does not have a formal set of such indicators, but parameters such as cost, adherence to time schedules and safety issues are monitored regularly by DD itself as well as by relevant stakeholders, as described below. In this context, the most important stakeholders are the Ministry, the nuclear regulatory authorities and politicians (the latter mainly if things do not go according to plans).

I–B.3. Financial and budgetary performance monitoring

As a state organization, DD receives annual budgets for its general operation, e.g. salaries, general maintenance of facilities, general waste management, and administrative expenses. When a particular decommissioning project is to be started, a specific budget for expenses not covered by the general DD budget must be approved by the Parliament's Finance Committee. In the approval process, this budget will be compared to the initial budget estimate for the facility in question. To date, the project budgets have been kept within the initial estimate and, therefore approval from the Finance Committee has probably been given without any comments.

The expenses for a particular decommissioning project, like all other DD expenses, are monitored in some detail by the management on a quarterly basis. Deviations from the budget are explained, and modifications of the budget may be made, typically shifting a particular expense from one period to another due to changes in the time schedule.

Once a year, DD must present its accounts to the Ministry of Science, Technology and Innovation, where the expenses for the decommissioning projects are followed closely.

I–B.4. Safety related performance monitoring

Before a decommissioning project can begin, the project plan must be approved by the Nuclear Regulatory Authorities. The project plan, the contents of which must be in accordance with the recommendations from the IAEA [I–B.3], includes descriptions of the facility, dismantling and demolition methods to be applied, as well as an assessment of radiological and conventional risks.

For each individual decommissioning project, a dose constraint is set up for personnel doses, e.g. 5 mSv/a. Doses are recorded on a daily basis by means of electronic dosimeters and on a monthly basis by means of TL dosimeters. Should an individual's dose approach the dose constraint (which has not yet been the case), action will be taken, for instance, by modifying working procedures or adding shielding.

As a particular set of performance indicators, DD has set up four safety targets, which may be adjusted at the start of each year. The safety targets and the degree that they will be met are publicized at central notice boards in order to keep all staff aware of the safety issues. The 2008 safety targets were as follows:

(1) To have no negative criticism from regulators and nor violations of the conditions for operation and decommissioning.
(2) There should be no unplanned effective doses above 1 mSv within one month or unplanned doses to extremities above 5 mSv within one week. For planned operations, the ALARA principle is always applied.
(3) There should be less than three occupational injuries, both large and small;
(4) All near-accidents and observations of occurrences and circumstances that could lead to occupational accidents must be reported.

The 2008 targets were met as follows:

— Target 1: It was met 100%.
— Target 2: It was not met because an abnormal occurrence resulted in an individual dose of 1.6 mSv. (The occurrence was not related to decommissioning activities as such, but occurred during handling of an industrial radiation source.)
— Target 3: It was not met; three accidents resulted in one or more days of sick leave; two incidents without sickleave.
— Target 4: Five near-accidents were reported, which is considered a reasonable picture increase raise safety culture among the staff. It is difficult to measure exactly how well the target is met since it depends on people's willingness to report mistakes made by themselves or their colleagues.

The above-mentioned results are part of the information given in DD's annual Working Environment Report, which is published on its web page (in Danish only) and submitted to the regulators and the Ministry.

One requirement in the Conditions for Operation and Decommissioning is that DD must have a certified quality assurance system for its work processes. DD has chosen to obtain a certification after the DS/EN ISO 9001:2000 standard. According to the certification, the certifying body will carry out regular audits. In addition, DD carries out internal audits once or twice a year. Thus, the degree of adherence to the certificate serves as a general performance indicator for the overall work processes as well as their safety related aspects.

DD's Clearance Laboratory has achieved accreditation for clearance measurements in accordance with the DS/EN ISO/IEC 17025:2005 standard. Also, this certificate is subject to regular audits by the certifying body. Furthermore, as part of the requirements of the certificate, the laboratory must participate in international intercomparison exercises where samples with contents unknown to DD are measured and the results compared to those achieved by other similar laboratories and to the true values, known only by the laboratory delivering the samples. These inter-comparisons are good performance indicators for the clearance measurements carried out by DD.

I–B.5. Monitoring adherence to time schedule

As mentioned in the introduction, Parliament decided that the decommissioning of all nuclear research facilities at the site should be carried out within a period of 11–20 years from 2003. This led to the definition of an overall project plan when DD was established. This project plan aims at completing all the decommissioning work in 2018, i.e. after 15 years, giving some flexibility compared to the ultimate deadline set by Parliament.

In the initial project plan, each individual decommissioning project was only specified to the degree of detail that could be reached based on preliminary plans. When the projects are being planned in detail, their detailed time schedules are entered into the overall plan — and the planning seeks to fit the project into the time frame set out in the original plan. To date, this has been possible. Updates of time schedules for individual projects are discussed monthly by DD management. Until now, no delays have been experienced that could affect the overall timeframe. Furthermore, a number of steps in the projects are established as milestones in DD's general annual plan and the adherence to this plan is reviewed quarterly.

In addition to the above-mentioned internal monitoring of the progress, performance contracts are entered into with the Ministry of Science, Technology and Innovation. The contracts, which cover three year periods, establish goals and milestones for current decommissioning projects, safety aspects and financial management as well as DD’s information activity. Adherence to the performance contract is reported to the Ministry in annual reports and at regular meetings among DD's management and the contact points in the Ministry.

I–B.6. Performance indicators for contractors’ work

When a contract is entered into, for instance, concerning demolition of a biological shield, it will obviously contain a time schedule as well as provisions for safety. The monitoring of the contractor's performance will be part of the project manager's daily work and, therefore, is not within the scope of the present description. On a longer term scale, however, DD carries out formal contractor evaluations after the completion of contracts (large or small). This is part of the requirements in the quality management system, and the evaluations will have an influence on DD's interest in using the contractor in the future.

REFERENCES TO ANNEX I–B

[I–B.1.] Danish Decommissioning, www.dekom.dk. (accessed on 16 Feb, 2010).

[I–B.2.] LAURIDSEN, K., Decommissioning of the nuclear facilities at Risø National Laboratory. Descriptions and cost assessment. Risø-R-1250(EN). Risø National Laboratory, Feb. (2001), http://www.risoe.dtu.dk/Risoe_dk/Home/Knowledge_base/publications/Reports/ris-r-1250.aspx (accessed on 16 Feb. 2010).

[I–B.3.] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series, No. WS-G-2.1, IAEA, Vienna (1999).

I–C. PERFORMANCE INDICATORS IN THE GREIFSWALD DECOMMISSIONING PROJECT, GERMANY

I–C.1. Introduction

In this annex, the focus will be put on issues that are specific to a decommissioning project, i.e. mainly dismantling, decontamination, material/waste management, financing and regulatory interface. Other typical project management issues, not specific to decommissioning, are treated below.

The Greifswald decommissioning project is a large project (5 WWER 440 reactors operated) [I–C.1]. The project is therefore confronted with several stakeholders and their requirements for a large and diverse number of indicators. Due to the size of the project, sufficient data are generated making it possible to develop a large number of indicators. For a smaller project, it is not sensible or possible to apply a large number of indicators. However, the basic approach applied to arrive at specific indicators for a decommissioning project will be more or less the same.

After some general considerations and definitions on indicators, the application of indicators in the Greifswald project will be briefly reviewed and the major stakeholders identified. The approach implemented to comply with their requirements will be described and illustrated with some specific indicators used, to obtain a better understanding of how the system works in practice. Finally, a preview of the present work underway in this area in the Greifswald project is presented, with the aim to create a single integrated management system. .

I–C.2. Basic considerations

I–C.2.1. Project indicators

What is an indicator? An indicator is a characteristic measure of the project status, which should reveal what is actually going on at any particular time and in any particular aspect of the project. The indicators will facilitate an appropriate control of the project, i.e. basically of time, money, resources and safety (including environmental issues), allowing for a trend analysis and forming the basis for decisions of necessary actions. To sum up, the indicators are used to:

— Measure a project's progress;
— Give a measure of project performance;
— Enable comparison between projects;
— Communicate with stakeholders.

Examples of indicators widely used in decommissioning projects are: units of material dismantled, units of waste disposed, dose commitment, number of waste areas closed, reduction in surveillance and maintenance activities, etc.

Due care must be taken that all boundary conditions are clear, so that the comparison with other project is made on the same basis. Such benchmarking against other projects can also be very useful to build stakeholder confidence in project performance.

What is meant by a performance indicator? What is the difference between a project indicator, a progress indicator and a performance indicator? 'Project indicator' is the general term covering all indicators in a project. The difference between a progress and a performance indicator can be illustrated by considering an example from a dismantling operation in a decommissioning project, as follows:

— Basic data: kg dismantled material; time required; number of people involved;
— Progress: % of plan (e.g. as dismantled material or time) achieved;
— Performance: kg/person-hour for certain boundary conditions, for example, different radiation protection areas (e.g. controlled area, supervised area or areas requiring full protection).

As can be understood from this example, the performance indicator represents a higher level in the indicator hierarchy. One can also imagine the combination of performance indicators to a still higher level. This has, not been applied, however, in the Greifswald project. The principal use of the different types of indicators as exemplified above in the Greifswald project is shown in Fig. I–C.1.

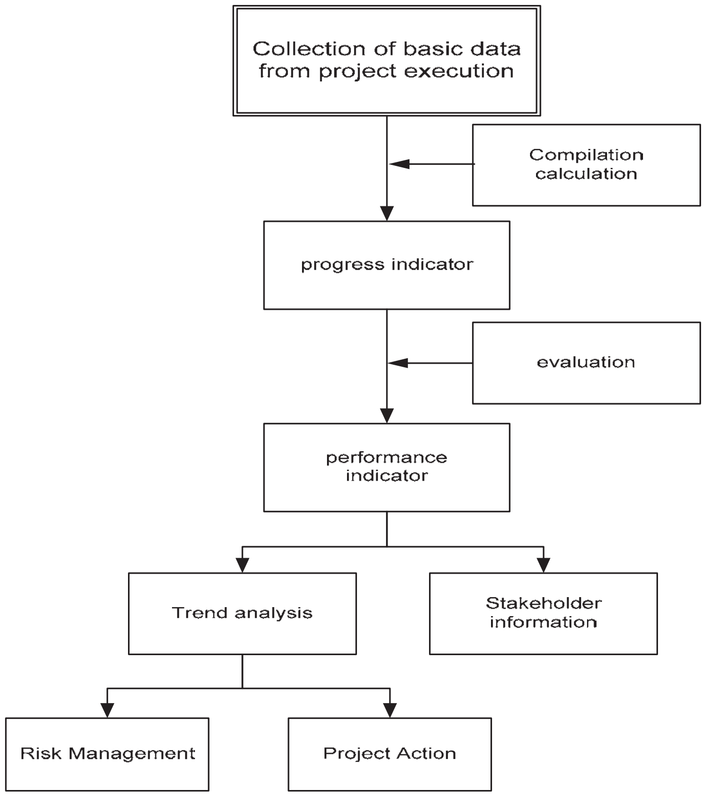


Fig. I–C.1. Schematic presentation of the use of indicators in the Greifswald project.

I–C.3. Basis for indicators

In order to obtain a useful and meaningful indicator, there must be a basis for comparison, which will consist of a detailed, reliable and transparent planning of the project. The only way to perform appropriate planning in a decommissioning project is by producing a reliable inventory of systems and facilities that have to be decommissioned, i.e. masses, material, contamination levels, activation levels and dose rates (ambient and hot spots). Only with this information is it possible to plan the dismantling operations and the material/waste management to the required level of accuracy for the project.

It can be concluded that when implementing an indicator, the basic data coming from the project execution also look at all project supporting activities. The measured raw data, registered supply of utilities and other information on, for instance, personnel and environmental analysis can be evaluated or compiled in such a manner that suitable indicators are formed to fit the project and stakeholder requirements.

I–C.4. Greifswald decommissioning project

I–C.4.1. Short project overview

EWN is running a major decommissioning project at the Greifswald site. At the site, eight units of the Russian designed reactor WWER 440 are located, including all necessary facilities to handle and store fuel and radioactive waste. Shortly after the reunification of Germany in 1989, the operating units 1–5 were switched off and the construction work at the nearly completely installed units 6–8 was stopped. After thorough investigations on the possibility to restart (after certain reconstructions) some of the units, no economically acceptable solution was found, and a decision was finally taken to decommission all units. For this purpose the Energiewerke Nord GmbH (EWN) was created with German Ministry of Finance as sole shareholder. Due to this decision, massive reductions of personnel were unavoidable, from around 5000 operational and 8000 construction staff to around 2000 employees.

The decommissioning strategy developed by EWN [I–C.2, I–C.3] combines immediate dismantling and decay storage of dismantled material. One of the key decisions taken at the project outset was to build a large interim storage on the site, equipped with treatment facilities for dismantled material. In a separate area of this interim storage, spent fuel in CASTOR casks can also be stored. With this strategy, it was possible to disconnect time consuming cutting and treatment of dismantled material from the actual dismantling operations in the plant. At the same time, this interim storage is used for decay storage of dismantled material when appropriate. Recently, this decay storage strategy has been extended to include also reactor vessels and their highly activated internals.

In general, the decommissioning of an NPP and most other nuclear facilities (not unique ones) does not present technical issues of major concern, but rather issues on project management and waste/material management, although it may involve intricate political and juridical boundary conditions.

I–C.4.2. Stakeholders

The importance of identifying the relevant stakeholders is vital in each project. In the Greifswald project, taking into account the specific site situation described above at the project initiation phase, the following major stakeholders have been identified:

— Ministry of Finance, as the owner supplying all financial resources for the project;
— Regulatory authority;
— Neighbouring communities;
— Trade unions (employees);
— Project itself (internal stakeholder).

These stakeholders have obviously different areas of interests in the project and thus require different information from the project and must be managed differently. For some stakeholders, basic information on the project status and company strategy is interesting and for others evaluated and/or compiled information from the project, in the form of specific data and performance indicators are required. The compliance with the requirements of these stakeholders will be discussed below after reviewing the indicator system applied in the Greifswald project.

I–C.4.3. Indicators

The basis of thorough planning of the project is a reliable inventory (material and radiological data) of the facilities to be dismantled. This does not mean, however, that it is necessary to register in too much detail before starting project execution. It is only necessary to go into such a detail so that dismantling activities and the waste/material management can be planned and implemented with sufficient accuracy for scheduling and resourcing. The detailed planning of the normal dismantling activities is performed shortly before execution, actual dose rate and contamination measurements are performed, and if required, more detailed material inventories are also made. How close to the start of execution the detailed planning is performed depends on, for example, the complexity of the dismantling operation and. budget restrictions.

In the Greifswald project, a very detailed methodology was developed, primarily for project planning purposes in order to obtain a reliable and transparent basis for the scheduling and the cost calculation. To achieve this, the project areas have been grouped in five categories with corresponding packages, see Fig. I–C.2.

This division originating from the planning generates the relevant project indicators for each package, which can subsequently be used in the project, as shown in Fig. I–C.1.

I–C.4.4. Compliance with stakeholders’ requirements

The major stakeholders have been identified above; here an attempt will be made to identify their requirements and to show how they are satisfied.

C1 Planning • Dismantling • Preparation of licensing documents • Building demolition • Conceptual planning • Waste management/transports • System decontamination • Fuel management	C2 Execution • Dismantling in supervised area • Dismantling in controlled area • Remote dismantling • System decontamination • Removal contaminated building structures • Building demolition
C3 New projects required as applicable	
C4 Waste Management • Treatment of rad. waste • Disposal • Containers and transport infrastructure • Free release and conventional disposal • Fuel and reactor core components	C5 Post- Operation • Documentation • Quality control • Storage of material, waste, fuel • Project management

Fig. I–C.2. Categories and packages for planning and monitoring.

Ministry of Finance

The complete budget for the project comes from the Ministry of Finance. Hence, it has a major interest to control that the money is spent appropriately. For the flow of financial resources, the generally accepted and/or required rules for accounting, balancing and transparent contracting procedures are applied. In addition, a specific system to control the performance of the project from another point of view has been implemented, as required from the Ministry of Finance. This system is not based on a comparison of planned versus actual status of the project and its subsequent analysis, but on the budget plan combined with specific tasks to be executed. In the budget plan, the following main groups are used:

— Licensing
— Dismantling
— Waste/material management
— Site operation
— New constructions (as appropriate).

In these areas, important and specific project relevant tasks are annually selected and fixed in an agreement between the project and the Ministry. The fulfillment of this agreement is checked by an external controller based on specific quarterly reports made by the project for this purpose. The controller subsequently drafts his/her report to the Ministry in a standardized simplified form, with ‘traffic lights’ (green, yellow and red) representing certain criteria. In this manner, a very simplified form of the status of the project is obtained, viewed from the financial point of view, but based on the project activities.

Here, a completely different approach to an indicator system has been introduced from a stakeholder in order to satisfy its requirements as budget controller at an upper level. Indicators as discussed below for the regulatory authority and for the project are, to a limited extent, used in the semi-annual reports to the Supervisory Board, in which the Ministry of Finance is represented.

Regulatory authority

This key stakeholder clearly needs special consideration and efforts from the project. First, it is necessary to establish a common understanding of responsibilities, roles and goals in the working relationship with project stakeholders, determining a clear basis and a progressive working atmosphere for the project implementation. The tasks to be preformed by the regulatory authority are divided into two parts in the FRG: licensing processes and site inspections and controls. In order to fulfill these tasks, the regulatory authority uses authorized experts to perform the detailed controlling of licensing documents and planning documents, and for most of the in-process controls.

The regular meetings of the regulatory authority and the authorized experts, are normally held bi-annually, at a high level (Technical Director, Head of the Licence Department, Head of Plant Operation, Head Regulatory Authority, etc.), i.e. at the decision making level. At these meetings, the project status, licensing situation and, in particular, existing or new licences needed are discussed and actions agreed. With respect to licence applications and issues related to the regulatory control, technical expert meetings take place as required. The authorized experts performing the regulatory control on site are due to the size of the project almost always present and have their own office on site.

In the framework of the regulatory control/surveillance of the post-operation and decommissioning activities, monthly (and yearly) reports have to be conducted, covering basically all project aspects except financial and scheduling issues, except when directly related to the regulatory activities. A typical basic table of contents is shown in Appendix I, together with examples of indicators used. These regular reports are distributed to the licensing authority and authorized experts involved, as well as to the Advisory Committee for Nuclear Issues mentioned above.

Neighbouring communities

Due to the geographically isolated site in a mainly agricultural area, the employment situation in the project has a major influence on the neighbouring communities (taxes, local companies, etc.). The influence on the communities was further enhanced by the very large number of persons employed at the time of closing down. Thus, the decision to stop operation and start decommissioning had a major impact on the local region. Thus, it is clear that they have a major interest in the project situation and the project/company strategy.

The information flow to the communities is secured with regular meetings with presentations and discussions of all important issues. Furthermore, the company directors have built up a network with the mayors and relevant officials. In the early phase of the project with the heavy personnel reductions, contact with employment agencies took place on almost a daily basis. To improve the employment situation in the region, a reuse of the site for industrial activities is supported as far as the company statutes it allows. In order to flexibly manage the site development for new industrial activities, the neighbouring communities have created different special purpose associations. This concerns three specific areas: site infrastructure, harbour, and water supply and treatment. In this way, it was possible to separate the costs for the site reuse activities from the decommissioning budget.

In order to further improve and intensify the communication in the region, the country and with different NGOs, an Advisory Committee for Nuclear Issues for the Greifswald site (Participants: EWN, politicians, NGOs) was created. This Committee meets on a semi-annual basis or as required from the participants.

Trade unions (employees)

Due to the dramatic personnel reductions required in the beginning of the project, the personnel situation was a key issue. Hence, this situation necessitated a very close working relation with the trade unions/employees' representatives. Working/information meetings took place weekly between the employees' representatives and the Personnel Department, and monthly with the participation of one company director. For the project execution, it is mandatory that the workforce is satisfied, especially that they have a clear job perspective (as far as it is possible in a decommissioning project). It is necessary to inform and discuss with the workers representative as early as possible when changes arise that influence the workplaces (number or quality).

It can be added that when a company has a certain size, there is also a workers representative in the Supervisory Board.

Project internal

The normal project controlling tasks and issues covering the comparison between the planned and actual status of the project, earned value analysis, etc. are treated in numerous publications and will not be repeated here; rather, some implementation aspects will be presented on how the Greifswald system works in the practice.

As shown above in Section 2.3, the project activities were broken down in five categories, each containing certain packages, as indicated in Fig. I–C.2. The activities at the package level are repetitive to a large extent. For example, with respect to dismantling works, certain tasks must be performed, and certain aspects must always be taken into account. In the planning phase, detailed planning documents, calculations and licensing documents must be prepared, and during the execution of dismantling tasks, standard tasks must be performed, e.g. working place preparation, radiation protection and material transport. All these work aspects must be taken into account in the planning and cost calculation of the project, and due to its repetitive nature, this is made with certain factors or surcharges. Subsequently, these factors and figures represent an ideal basis for the decommissioning project indicators at this level.

To obtain a clearer picture of how this system works, an extract of the factors included for certain packages are shown in Appendix II, and for selected cases, typical numerical values are given. The values given are only indicative and to a large extent, project specific. The factors and surcharges are evaluated when a task or working package has been closed and the results are available. The influence of revised factors on the overall project is estimated and reviewed in specific project meetings, which are held as required. In these meetings, the need for more detailed calculation is determined and eventually the project is revised. When the project has been in operation for some time and data have been collected, there will be a good basis to evaluate its performance.

The regular project reporting is performed dually on a monthly basis; one report is prepared by the Project Control Group and issued by the Project Manager; the other one is prepared and issued by the Finance Department:

The Project Progress Report basically covers the following aspects:

— Status of licensing conditions and licence applications.
— Project works descriptive review
  • Dismantling
  • Remote dismantling
  • Waste/material management
  • Reconstruction
— Status of project, summarized presentation of planned-actual status of time, money and dismantled material
— Status of waste management

The Management Report is based on the budget plan and the planned cash flow, and covers the following issues, in a graphical form:

— Project status, planned versus actual situation;
— Selected repeatable expenses for containers, packages, utilities;
— Radioactive wastes produced and accumulated
— Personnel situation.

This report also covers the site operation, i.e. the costs and person-hours according to the budget titles for all departments in the company.

This dual reporting, with partly overlapping coverage, has been intentionally introduced in order to check important aspects of the status of the project from different points of view. It has turned out to be a good approach, but normally only worthwhile for a large project.

I–C.5. Present optimization of EWN indicator system

Today, every company and project have a range of management systems, covering the different company/project aspects such as quality, risk, health and safety, security, environmental issues, waste/material, project execution, financial issues and personnel. These systems are to a large extent covering the same aspects, but from a different point of view and with a different level of priority (see Fig. I–C.1). In order to handle all of these management systems, it is advisable to establish an integrated management system. Work towards this goal is underway at the international and national level, and proposals and guidelines have been issued [I–C.4 to I–C.6].

Also, in EWN and specifically in the Greifswald decommissioning project, the pressure to establish different management systems and to fulfill their requirements is extremely high, notably from the Regulatory Authority and the fund provider (Ministry of Finance). However, in order to fulfill those requirements while keeping the project running without excessive non-productive costs, it is mandatory to establish a workable system, not just producing papers. A system is required that truly makes a contribution to safety, transparency, reproducibility and stakeholder communication. The output of such a system at a condensed level will be in the form of indicators (in this case, KPIs). Thus, there is a logical connection between the indicator system and the integrated management system.

In order to establish such an integrated management system, the starting point is the existing risk management system and the safety management system required by the licensing authority. In general, all issues of interest and importance for the project and the various stakeholders also represent a potential risk to the project. For controlling and reporting on the risk status of the project, suitable indicators are required, which can be used to satisfy the stakeholders' requirements. To sum up, it can be stated that all stakeholders requirements must be covered in the risk management system and that looking the other way around, all risks identified can be allocated to a stakeholder.

Parallel to these activities on the existing risk management system, the implementation of a Safety Management System is in process. This system is required by the licensing authority, not only for operating, but also for nuclear plants under decommissioning. In order to establish such a system, a bottom-up approach was taken, i.e. all processes in the project including all site activities were documented and analysed. In a second step, the safety relevant processes were identified and indicators defined for the use in the safety management system. However, on the basis of the complete process inventory, all processes had been identified and could be used as a basis for the creation of an integrated management system. Combining the results from the investigations, an integrated management system can be established and implemented in a practical manner (Fig. I–C.3).

It must be clearly noted here that, with the introduction of an integrated management system, the objective is not to perform fundamental changes in the existing operational management structures (line organization), but to analyse how the work is actually performed, define indicators and to improve the workflow processes where appropriate.

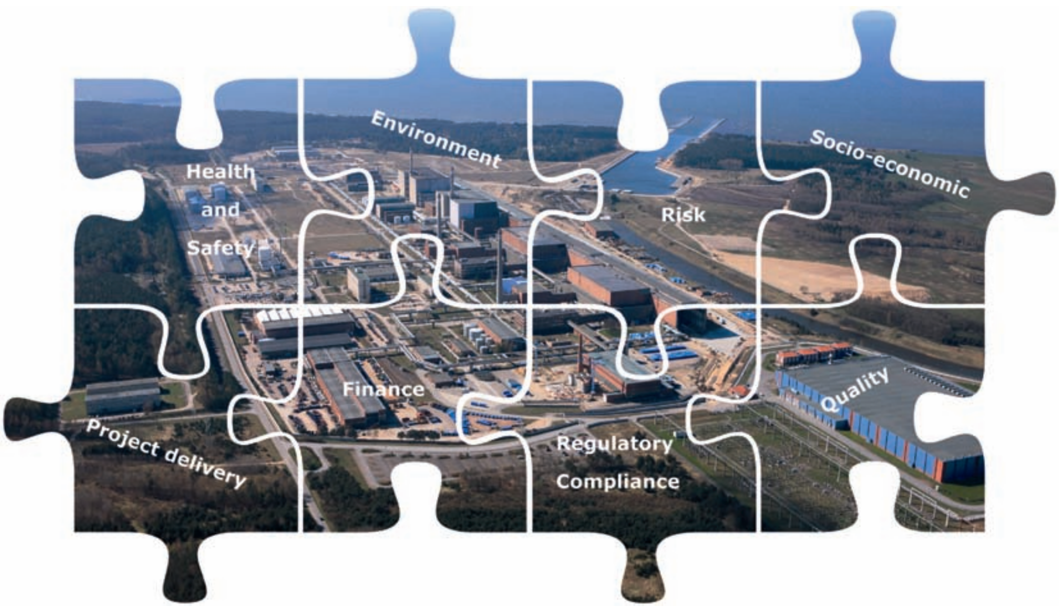


Fig. I–C.3. Symbolic presentation of the interaction between management systems.

REFERENCES TO ANNEX I–C

[I–C.1] FRANK, C., STERNER, H., “Fifteen years practical decommissioning experience at Greifswald NPP”, CEE Conf. on Decommissioning and Waste Cooperation in Berlin, 18–19 June 2008, IBC Global Conferences.

[I–C.2] BEHRNDT, H., et al., Long-term Interim Storage and Release of Radioactive Material, 6th Int. Symposium on Release of Radioactive Material from Regulatory Requirements, Wiesbaden 21–23 Sep. 2009, http://www.tuev-nord.de/de/unternehmen/Messen__Veranstaltungen_1829_DEU_RRM-Symposium_2009_28418_DEU_PRODUCTIVE.htm (accessed 12 Feb. 2010).

[I–C.3] STERNER, H., RITTSCHER, D., The Greifswald WWER Decommissioning Project — Strategy Selection. Proc. Seminar Tarragona 1–4 Sep. 2003, NEA No 5300, OECD, Paris (2004).

[I–C.4] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, IAEA-TECDOC-1141, IAEA, Vienna (2000).

[I–C.5] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006).

[I–C.6] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the management system for facilities and activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

APPENDIX I TO ANNEX I–C

Typical content of regular report on decommissioning and post operation to external stakeholders

(1) Review post operation
- Production/consumption data (steam, electricity, fuel/gas).

(2) Decommissioning and dismantling
- Regulatory: status of licence conditions, changes of licences or applications.

(3) Project status
- Review of work performed
- Controlled area
- Supervised area
- Reconstruction/Maintenance measures
- Dismantling activated components
- Waste management.

(4) Regulatory reporting
- Air and water emissions
- Dose commitment
- Environmental data: water consumption, water treatment, production demineralized water, discharges to sea.

(5) Material flow
- Free release with or without restrictions
- Radioactive waste.

(6) In-service inspections
- List of inspections for the different facilities.

(7) Maintenance and repairs works

(8) Incident reporting
- Licensing conditions not fulfilled, injuries, fire incidents.

(9) Warm workshop for treatment of dismantled material.

Separate reports are made for the interim storage and for spent fuel.

Indicators are used in connection with the regulatory authority.

All of these indicators are statistically followed over the complete project time. Note that ‘%’ means percent of yearly planned value.

No. of licences/approvals needed	% of total or yearly basis
— with public participation	Yes/No
Regulatory costs	yearly basis
Inspections on site	%
System control checks	%
Free release approvals required	%
Transport approvals of waste/fuel required	%
Non-scheduled visits	number/a
Incident reports to authority	number/a
Limit over passed	number/a
Time spent on regulatory matters	% of project person-hours.

APPENDIX II TO ANNEX IC

Examples of specific values of indicators in the Greifswald project

Planning

- — Dismantling
  - • 5–10% of dismantling costs
- — Preparation of licensing documents
  - • 10% of dismantling costs
  - • Material costs: case by case
  - • Regulator costs: case by case
- — Building demolition
  - • 10% of demolition costs
- — Conceptual planning
  - • 5% of dismantling costs
- — Waste management/transports
  - • 10–15% of costs
- — System decontamination
  - • 2–4% of decontamination costs

Execution

— Dismantling in supervised area	
regulatory documents	5–10%
working place preparation	2–6%
• removal insulation 0.05 Man–h/kg	
• dismantling 0.02Man–h/kg + factors and surcharges for:	
∘ case by case, special technologies required	x 0.5–3.5
∘ removal without dismantling	x 0.6–0.9
∘ lack of space	x 1.20–1.4
∘ lifting device needed	x 1.3–1.5
∘ large components removal	x 0.5–1.5
∘ internal transport	10%
∘ radiation protection	2–6%
∘ documentation	2%
∘ support infrastructure	2–5%
— Dismantling in controlled area	
• regulatory documents	10–15%
• working place preparation	10–15%
• removal insulation 0.19 person-hours/kg	

- dismantling 0.025 person-hours/kg + factors and surcharges for:
  - case by case, special technologies required x 0.5–3.5
  - removal without dismantling x 0.6–0.9
  - lack of space x 1.2–1.5
  - lifting device needed x 1.3–1.6
  - large components removal x 0.5
  - internal transport 20%
  - radiation protection 10–15%
  - decontamination 11–15%
  - documentation 2–3%

— Remote dismantling
— System decontamination
— Removal contaminated building structures
— Building demolition.

I–D. DESIGN AND USE OF PERFORMANCE INDICATORS IN VANDELLÓS I DECOMMISSIONING (SPAIN)

I–D.1. Introduction

Vandellós I was the first nuclear power plant (NPP) to be dismantled in Spain and one of the first large commercial plants to be decommissioned in the world. For this reason, its partial dismantling to Level 2 was a pioneering experience in all respects.

It began operation in 1972 and was then the second oldest NPP in Spain. It was dismantled long before reaching the end of its service lifetime as a result of a fire in 1989, classified as a Level 3 incident on the INES scale. ENRESA designed and implemented the dismantling project, which reached Level 2 in a period of five years (1998–2003), releasing 70% of the land on the site. The cost of decommissioning the plant was EUR 94.6 million and the average number of people were involved was 323.

Planning of the works was carried out through the Dismantling and Decommissioning Plan, which focused on three types of activities:

— Activities in conventional areas: These activities consisted of dismantling buildings, systems and components located in areas without any radiological implications;
— Activities in active areas: These activities related to the disassembly, segregation and transfer of elements located in contaminated areas;
— Preparation for the dormancy phase: This consisted fundamentally of confining the reactor shroud, implementing the infrastructures for the dormancy phase and preparing the official standards applicable to this situation.

The control of these activities was designed on the basis of a series of parameters comparable to the current performance indicators concept, which was not contemplated at the time. The data used to control the evolution of the tasks were grouped into ten sections:

(1) Work progress
(2) Staff labour
(3) Control of costs and the socio-economic impact in the surrounding area
(4) Materials management
(5) Radiological impact
(6) Prevention of occupational risk
(7) Quality
(8) Training
(9) Communications
(10) Integration of indicators.

The indicators defined for each section showed the progress of the works, together with the success of the tasks performed or deviations with respect to the objectives mapped out. The recording of the data generated in the different activities was a fundamental building block that allowed the progress of the dismantling to be controlled and the incidents hindering achievement of the objectives to be corrected.

A key aspect for the correct use of the indicators was the assignment of the stakeholders or people receiving these data, which shaped the entire dismantling communications policy. In order to ensure that stakeholders intervening directly or indirectly in the project had available adequate information, a map of potential users was drawn up. The aim was to provide full information but without overwhelming the stakeholders with data that they did not know how to interpret or with data referring to certain areas of the project for which they were not responsible. Communications with these stakeholders were established as a dismantling support and tracking area.

The stakeholders map was configured as follows:

(a) Internals
  (i) Works management
  (ii) ENRESA management
  (iii) Persons with responsibilities in dismantling (heads of services)
(b) External
  (i) Regulatory authorities (CSN, ministries)
  (ii) Tracking Commissions
  (iii) The media and public opinion leaders
  (iv) Visits
  (v) Professional stakeholder groups.

The internal works management stakeholders received overall indicators of the different areas of activity at all levels (daily, weekly, monthly and on key dates). ENRESA Management controlled the overall works indicators monthly and on key dates. The heads of services received only indicators relative to their respective areas of responsibility and adjacent areas, including tasks on which they had an influence, these being received daily and weekly. Every month and on key dates, they received the same indicators as the rest of the internal stakeholders.

The group of external stakeholders was classified in two major areas or channels: institutional communications (mandatory) and social communications. The first, known as the Information Committee for the Dismantling of Vandellós I, was made up of the Ministry of Economy, the Ministry of the Environment, the Nuclear Safety Council, the Town Council of Vandellós-L'Hospitalet de l'Infant, the Regional Government of Catalonia and the Office of the Central Government in Catalonia. These stakeholders were provided with all the performance indicators corresponding to the dismantling works. The channel for social communications, which was not required by law, was formalized through the Municipal Tracking Commission for the Dismantling of Vandellós I, consisting of representatives of the municipal area of Vandellós, of the five municipal areas closest to the plant, and of different citizen organizations. In addition, an independent go-between from the Rovira i Virgili University (Tarragona) was set up to advise the members of this municipal commission on any technical issues raised. For these stakeholders, performance indicators were selected for areas referring to the evolution of the budget, the economic impact in the area and environmental impact.

I–D.2. Indicators

I–D.2.1. Works progress

The period for performance scheduled in the project was 60 months, a deviation of 5% occurring on completion of the works. The level 2 dismantling of the Vandellós I NPP thus took 63 months in total.

The dismantling planning project separated the works into activities, on the one hand, and areas of activity (buildings), on the other. This allowed the evolution of the dismantling work to be controlled for each activity and specific physical area, also allowing for the correction of delays initiating in one area and possible later spreading to others. For detailed illustration of the above, refer to Table I–D.1.

TABLE I–D.1. WORK BREAKDOWN AND PROGRESS DURING VANDELLÓS DECOMMISSIONING

APRIL 2003	Thermal isolation dismantling		Conventional parts dismantling		On site decontamination		Radioactives parts dismantling		Reactor vessel isolation		Building's decontamination		Building's rad. Reclassification		Building's demolit. and restoration		Advanced task by buildings
Buildings	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	Mosth advance	Acumulate	
Reactor building	0%	100%			0%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100%	100,0%
Auxiliary building	0%	100%			0%	100%	0%	100%			0%	100%	0%	100%	0%	100%	100,0%
Fuel building	0%	100%			0%	100%	0%	100%			0%	100%	0%	100%	0%	100%	100,0%
Spent fuel pools building					0%	100%	0%	100%			0%	100%	0%	100%	0%	100%	100,0%
Liquid radw.treat.building					0%	100%	0,4%	99,4%			6%	98%	5%	80%	40%	45%	82,7%
Laundry building					N/A		0%	100%	N/A		0%	100%	0%	100%	0%	100%	100,0%
Silos & Inst. for graphite treat.	N/A				0%	100%	0%	100%			0%	100%	0,3%	99,0%	0%	100%	97,6%
Solid radwaste pits					N/A		N/A				0%	100%	0%	100%	0%	100%	100,0%
Drums silo							0%	100%			0%	100%	0%	100%	0%	0%	60,0%
Externals areas							0%	100%			N/A		N/A		N/A		100,0%
Turbines building	N/A		0%	100%											0%	100%	100,0%
Auxiliary building			0%	100%											0%	100%	100,0%
Auxiliary steam plant	0%	100%	0%	100%											0%	100%	100,0%
Chemical neutralization pit			0%	100%											0%	100%	100,0%
Demineral. water instal.			0%	100%											0%	100%	100,0%
Fuel-oil & gas-oil tanks	N/A		0%	100%											0%	100%	100,0%
Externals areas			0%	100%											0%	100%	100,0%
Administration building			0%	100%											0%	100%	100,0%
Maintenance building			0%	100%											0%	100%	100,0%
Workshops building			0%	100%											0%	100%	100,0%
Others conv. Instalations			0%	98%											0%	99%	98,5%
	100%		99,0%		100%		99,6%		100%		98,9%		99,0%		99,3%		

Furthermore, all the works progress data were centralized in a single graph allowing insight into the project evolution curve. In this way, it was possible to rapidly view the progress of the dismantling with respect to the scheduled target date. This overall indicator was of key importance as regards learning of the progress of dismantling since it allowed for the detection of those moments at which the work slowed down or speeded up. Figure I–D.1 shows a record of the evolution of the works.

I–D.2.2. Staff labour

The dimensions of a project for the dismantling of a plant on an industrial scale imply the intervention of a considerable team of people, with the number of individuals varying with time (2700 workers over a period of five years with a peak number of 420). Furthermore, the works were not performed by a single company centralizing all the contracting, but through the intervention of numerous contractors in different areas and with different areas of expertise. In total, 63 companies participated, with an average of 30 on site. This made it necessary to thoroughly control the working days, which was achieved through four indicators:

— Overall level
— By contractor
— By activity
— By service.

This indicator is important because it provides an image of the operation of the different services or activities. Figure I–D.2 shows the evolution of personnel contracted, broken down into different services.

I–D.2.3. Control of costs and socioeconomic impact

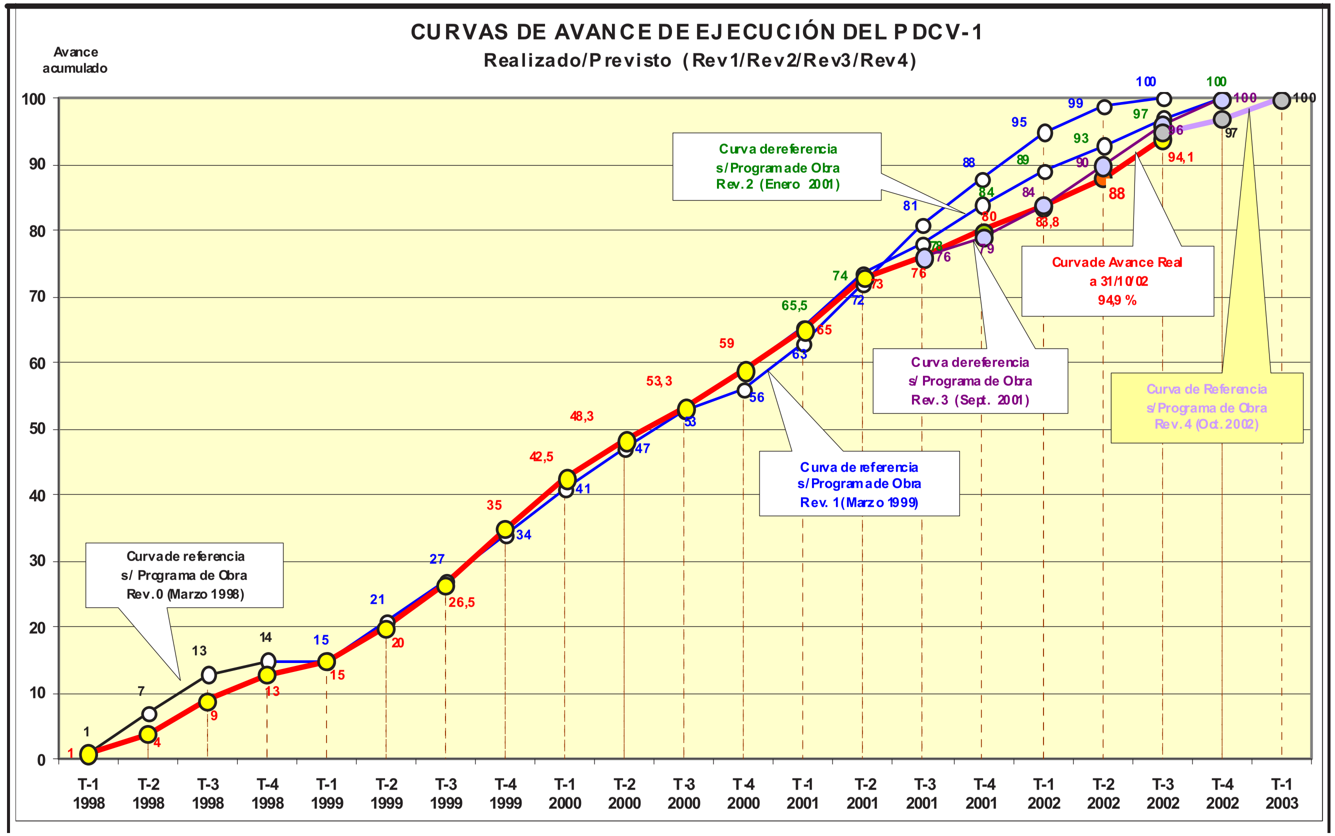
The contracting policy applied by ENRESA consisted of distributing the work among a large number of companies in order to promote the involvement of the local economic fabric. The cost indicators were required to reflect an image of the money spent in relation to each task to be performed. To accomplish this, the monitoring of the expenditures was carried out through four areas:

— Contracts: Contracts belonged to two major groups, fixed price and reviewable price (for activities implying possible contingencies, such as the purchasing of radiological protection equipment and the characterization of walls);
— Major dismantling programme activities;
— Services (staff, laboratory personnel, dosimetry, etc.);
— Intervention areas.

The final result was as follows:

— Official budget POA-PM 1998/2003: EUR90,906,000;
— Final cost of works: EUR94,605,769;
— Devision 4%.

In addition to controlling the initially scheduled budget, ENRESA planned on being aware at all times of the economic impact of the project on the surrounding environment. In particular, the number of participating companies and their origin — local, provincial, autonomous community or national — was periodically reviewed. The indicator providing the respective information was the ‘origin of the companies in percentage terms with respect to the total’. This was noted in a table in order to view the evolution of this parameter over time and thus compare the weight of local companies, for example, with respect to the national companies overall. Another indicator of socio-economic impact used was the percentage and evolution of the money invested in each of these geographical environments (local, provincial, autonomous community and national). A third indicator was the number of workers from each environment. Finally, an indicator was developed to reflect the induced (indirect)



TRANSLATION:
DISMANTLING PROGRESS CURVE
Done/ Scheduled (rev. 1/2/3/4)

Reference curve. Programme of Works. Rev 0 (March 1998)

Reference curve. Programme of Works. Rev 1 (March 1999)

Referente curve. Programme of Works. Rev 2 (January 2001)

Reference curve. Programme of Works. Rev. 3 (September 2001)

Real Advance curve on 31/10/02 94,9%

Reference curve of Works scheduled. Rev. 4 (October 2002)

FIG. I–D.1. Dismantling progress curve.

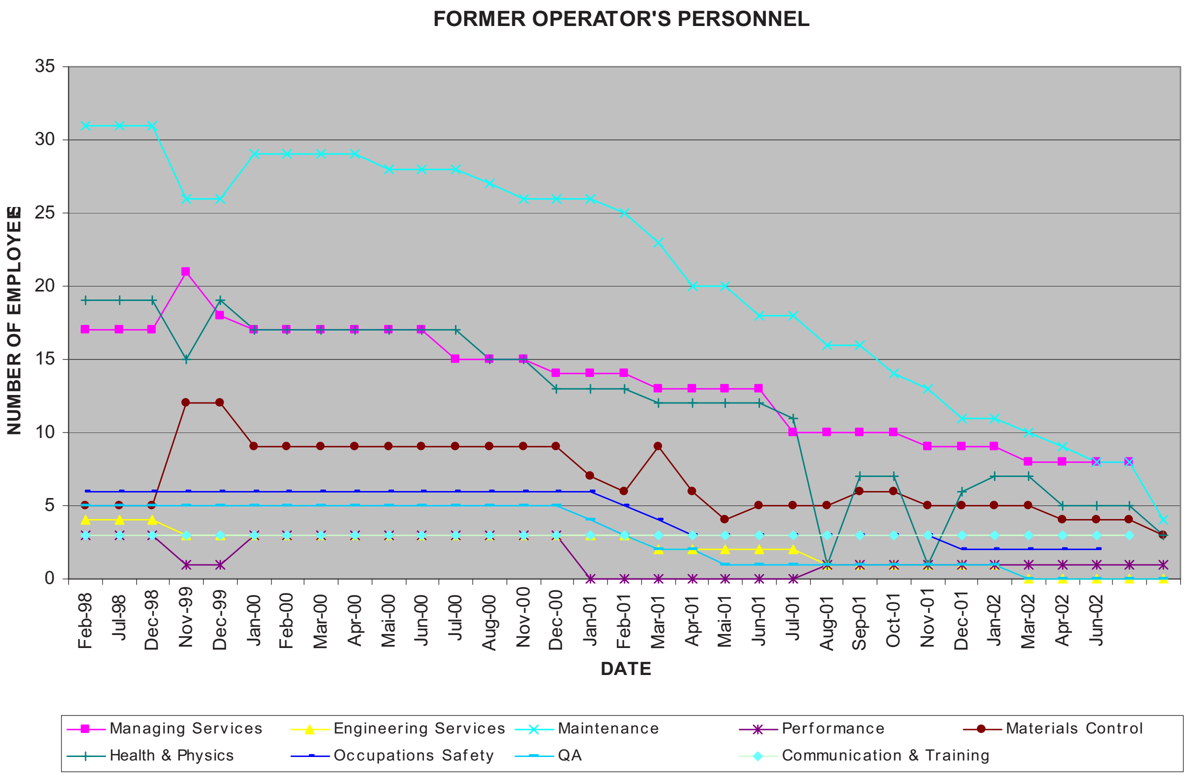


FIG. I–D.2. Personnel evolution indicators.

TABLE. I–D.2. TYPES OF INDICATORS OF ECONOMIC IMPACT

- % of local companies over the total
- % of provincial companies over the total
- % of autonomous community companies over the total
- % of national companies over the total

- % of money invested in the local environment
- % of money invested in the provincial environment
- % of money invested in the autonomous community environment
- % of money invested in the national environment
- % of money injected into local area

impact on the local economy arising from the benefits generated by the dismantling for the companies and workers intervening in the works. In summary, the indicators used are specified in Table I–D.2:

I–D.2.4. Materials management

There were numerous materials that had to be managed during dismantling to be organized in different areas. Furthermore, since it was necessary to set up temporary storage areas, the project included the definition of the areas whose use would need to change for the storage of different materials prior to their dispatch from the plant. A time span is assigned to these areas to serve as a transitory store, after which they will be demolished. Accordingly, indicators were designed including data on the characterization of temporary storage and materials control areas. The basis of the materials indicator recording system was as follows:

(1) In situ control (data recording):
   — Area of origin of the material (Intervention Unit)
   — Date
   — Radiological characteristics
   — Origin
   — System
   — Type of material
   — Weight
   — No. of packages.
(2) Classification of material:
   — From active areas:
      • Declassifiable
      • Declassified and evacuated
      • Radioactive waste
   — From conventional areas.

The data collected were used to establish indicators making it possible to quantify the wastes generated and visualize their traceability and deviation from the desired parameters. The main indicators were as follows:

— Number of packages per unit of time (working day, monthly, quarterly, annually and specific works completion limit date). The package/time unit register was performed for each intervention unit in the different areas of dismantling;
— Percentage of declassified material relative to unit of time (% decl. mat. /T);
— Number of declassified packages over total of processed materials (decl. packages/total materials);
— Percentage of rejections over total packages measured (% rejections/packages measured);
— Percentage of radioactive wastes generated in each intervention unit (% waste/IU);
— Square metres of declassified surface relative to the total surface to be declassified (m^2 declassified/TS);
— Declassification costs (euros/tonne of material).

Another fundamental objective defined was the reuse of materials as a way of reducing wastes and minimizing the entry of new materials required for the works, which would subsequently need to be managed as wastes, thus causing a greater environmental impact and higher economic costs. The planning consisted of drawing up an inventory of the existing materials and of grouping them by families in order to later compare them to the needs of the works and decide which might be reused. Significant examples of material reused are leaded windows or concrete slabs, which are being used as shielding during the dormancy period. The indicator that provided information on the level of reuse of materials was kg of material reused/total kg of material managed.

I–D.2.5. Radiological impact

The fundamental axis of Safety and Radiological Protection was an estimate of the collective dose (mSv/person) and its control with respect to actual dose. The initial data showed an important deviation with respect to the estimate, which was subsequently corrected. The ALARA measures implemented allowed the actual dose to be kept below the estimated dose in all cases, as shown in Fig. I–D.3.

The radiological classification of the different zones was particularly dynamic and linked to the scope of the project. Tracking the number of radiological zones compared to the total gives an idea of the typology and relevance of the work performed at each moment, as shown in Fig. I–D.4.

Another aspect of radiological impact that was thoroughly managed was environmental control. Environmental radiological surveillance plans were established, which contributed particularly to alleviating external stakeholders' concerns because it was possible to constantly monitor if there were no radiological effects off site. Several points were selected around the site for sampling of the different elements. Their analysis was established on the basis of different time frequencies, depending on potential environmental impact. The indicator used was the percentage of anomalous values with respect to the measurements performed per geographical area under study.

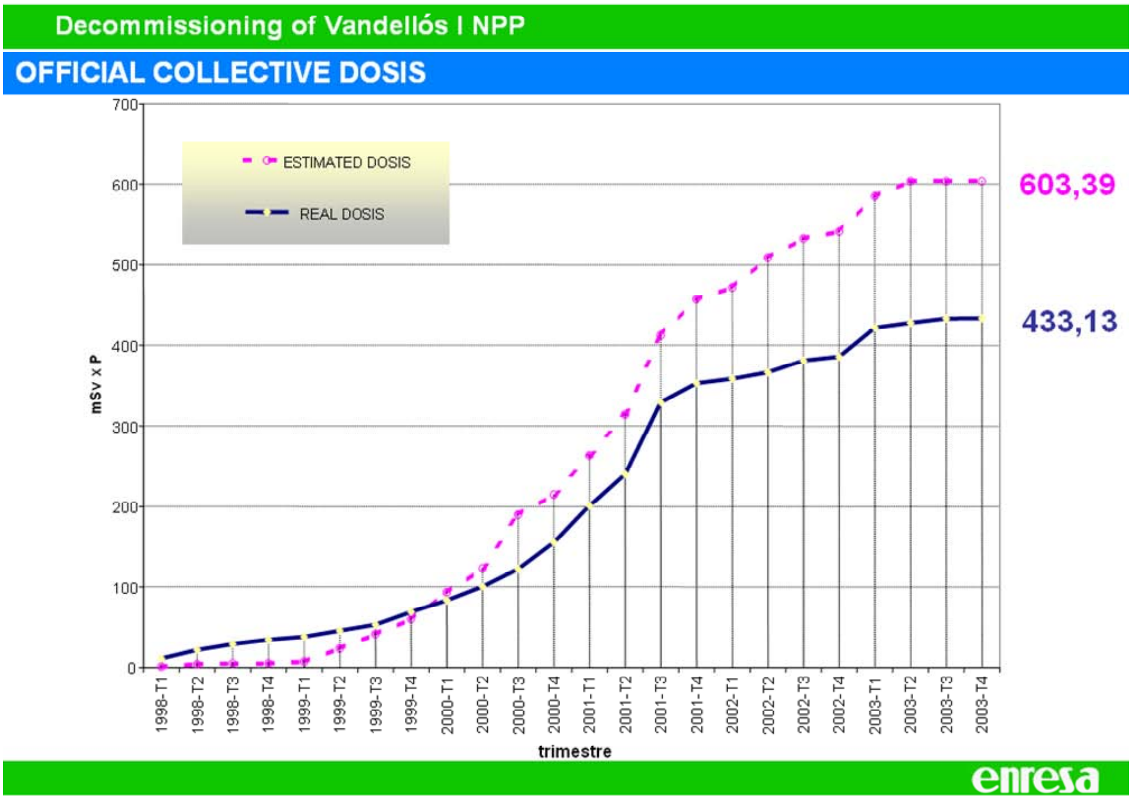


FIG. I–D.3. Evolution of estimated and actual collective dose.

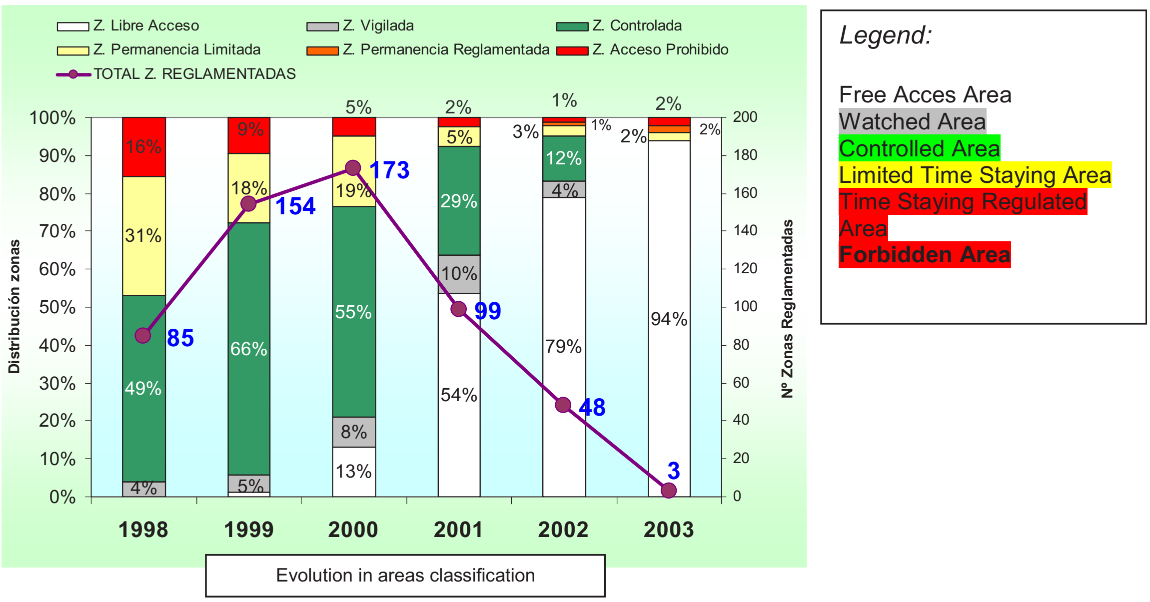


FIG. I–D.4. Evolution of areas classification.

I–D.2.6. Prevention of occupational risk

The prevention of occupational risk has been especially important in the works, and its management was conditioned by the passing of the Law on the Prevention of Occupational Risk in 1996. The reference used in establishing the performance indicators was the accident rate in the Spanish construction industry. A group of indicators was used to quantify different prevention actions, as follows:

— Number of specific potential risk assessments;
— Number of hours of training delivered;
— Percentage of hours dedicated to prevention tasks over the total number of working hours (days): % hours of prevention/hours in working day.

As regards the control of the evolution of effective work performance, data were collected on the number of accidents and days of work lost as a result of absenteeism, which were converted into indicators of the following:

— Number of incidents occurring;
— Assessment inspections / days worked;
— Number of deviation dockets / total number of inspections;
— Accident frequency index;
— Accident seriousness index;
— Days of work lost due to absenteeism/total number of working days scheduled.

The results produced the following:

Hours worked	2 750 000
Days worked	343 750
Prevention controls	12 000
Specific risk analyses	4950
No. of accidents	2
No. of incidents	83
Days lost due to absenteeism	0.4%

I–D.2.7. Quality

Quality control in the evolution of dismantling was undertaken by recording open non-conformities per unit of time and the average time taken to close them. These controls were implemented by areas of activity and integrated into various indicators, such as the number of non-conformities open in each area of management or the average time taken to resolve them.

I–D.2.8. Training

The training of the workers intervening in dismantling was an aspect that attracted a great deal of attention and to which many resources were dedicated. The objective was to prepare the workers and increase their awareness of the specific risks inherent in dismantling, for the safety measures applicable to their occupational activity to be adopted. The following indicators were established in this area:

— Number of courses delivered per year;
— Number of courses delivered by type (radiological protection, safety, emergency plan, etc.);
— Number of trainees attending;
— Number of refresher courses on safety culture (also relating to the prevention of occupational risk).

This planning provided the results shown in Fig. I–D.5.

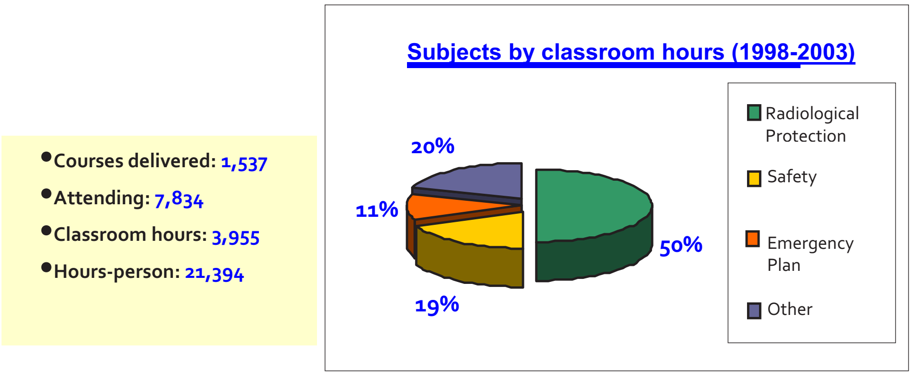


FIG. I–D.5. Results of training activities.

I–D.2.9. Communication

The communication actions were based on the principle of transparency, which translates in practice into number of visits from all types of target audiences and periodic open meetings with the media. The visits were classified into groups from schools, institutional visits and visits from citizens' associations. The indicators used to control their success were as follows:

— Number of visits per unit of time;
— Number of visits by geographical area;
— Number of visits by groups of interest;
— Acceptance surveys on dismantling.

The media were also considered stakeholders to whom information should be provided. Two general annual meetings were systematically established with the media through press releases, in order to inform them of the evolution of the dismantling (12 in total). Furthermore, ENRESA tracked the news items (762) on the dismantling in terms of their positive/negative impact.

In all areas, the information gathered by ENRESA had a qualitative impact in which a general attitude of social acceptance was detected.

I–D.2.10. Integration of indicators

On completion of the dismantling, all the data obtained were integrated in order to contrast them and generate new indicators providing a greater general understanding of dismantling. For example, the economic information was contrasted with the technical information to give an indicator referring to the doses received versus the hours worked and, therefore, to the economic cost. The philosophy of this integration of indicators may be visualized in Fig. I–D.6.

I–D.3. Process based management: methodology for future dismantling projects

On the basis of the experience acquired during the dismantling of Vandellós I and the decommissioning of the nuclear facilities of the Centre for Energy-Related, Environmental and Technological Research (CIEMAT), ENRESA is currently in the phase of defining a common methodology for the performance of future dismantling projects. This work implies the drawing up of a process map identifying performance indicators for each case. The conceptual basis consists of considering the different tasks to be performed as processes, the evolution of which needs to planned and controlled from beginning to end. Table I–D.3 illustrates the training process.

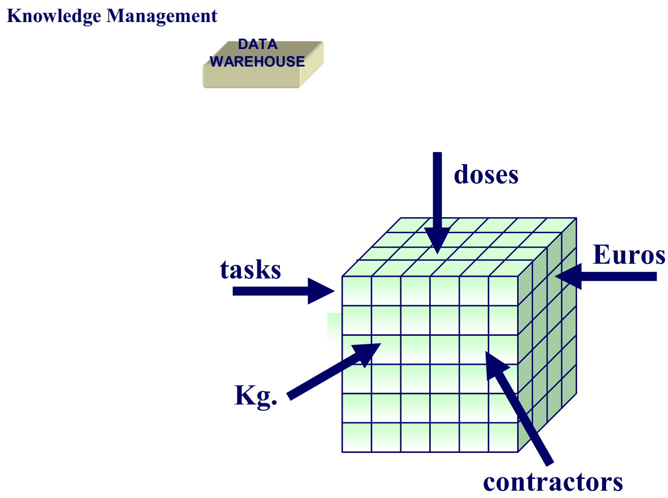


FIG. I–D.6. Investigation of indicators of Vandellós project.

I–E. EXPERIENCE AND OBSERVATIONS ON THE USE OF PERFORMANCE INDICATORS IN NUCLEAR FACILITY DECOMMISSIONING IN THE UNITED KINGDOM

I–E.1. Introduction

This national annex summarizes experience in the UK with respect to the selection and use of performance indicators (performance indicators) in nuclear decommissioning.

In the UK, key stakeholders involved in nuclear decommissioning are:

(a) Nuclear site licensees and their Parent Body Organizations (PBOs)
(b) The Nuclear Decommissioning Authority (NDA)
(c) The regulators
(d) The Ministry of Defence.

Experience is categorized according to these key stakeholders, with particular emphasis on the NDA and the regulators in order focus on civil nuclear liabilities because both the NDA and the regulators have responsibilities that encompass a significant number of nuclear site licensees.

This national annex provides a factual summary of key work relating to performance indicators in nuclear decommissioning, referencing publicly available information where possible. An appraisal of this work is not provided.

I–E.2. Scope and clarification

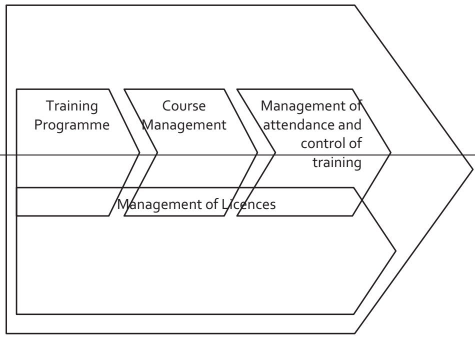
The scope of this annex only addresses nuclear decommissioning at NDA sites. This is not considered to be a significant restriction since this represents about 85% of the UK's civil nuclear liabilities [I–E.1].

In the UK, a number of regulators have responsibilities relating to nuclear sites (see, for example, paragraphs 1.30–1.33 of Ref. [I–E.2]). This annex only considers the work of the Environment Agency (EA) and the Nuclear Installations Inspectorate (NII), which is the part of the Health and Safety Executive (HSE) to which the nuclear site licensing function is delegated.

The NDA operating model is shown in Fig. I–E.1 of Ref. [I–E.3]. It involves PBOs in addition to nuclear site licensees. For the remainder of this annex, no distinction is made between PBOs and nuclear site licensees since this would have no material effect. For brevity, the term 'licensees' is used.

TABLE I–D.3. TRAINING PROGRAMME AND RELATED INDICATORS FOR THE DECOMMISSIONING OF JOSÉ CABRERA NUCLEAR POWER PLANT

Process	Training
Objective	To provide all the workers involved in the dismantling of the José Cabrera Nuclear Power Plant with the knowledge required to guarantee their safety and perform their functions adequately and safely, in addition to complying with the requirements imposed by the standards in force.
Owner	Training Department/Training and Communications Service

Start	Scope	End
— Drawing up of Training Plan		▪ Input of data on training to the computer application
Inputs		**Outputs**
— Personnel — Trainer(s) — Teaching material		▪ Workers trained in the areas defined in the DDP Training Plan of the José Cabrera Nuclear Power Plant (JC NPP) and requested by the Service Managers

Planning
— 060-PL-RR-0001 Personnel Training Plan for the Dismantling and Decommissioning of the José Cabrera Nuclear Power Plant
Operating Documentation
— 000-PC-EN-0013. Planning and Follow-up of Training — General Procedure for Training Activities within the DDP of the José Cabrera Nuclear Power Plant (Draft version)
Support Process and Documentation
— Documentary Management • 000-PC-EN-0020. Procedure for the Issuing, Control and Distribution of Internal Standards Documentation • 000-PC-EN-0021. Procedure for Acceptance of the Documentation Prepared by Suppliers — Purchases Management • 000-PC-EN-0018. Awarding and Contracting of Works, Goods and Services. — Quality Assurance • 000-PC-EN-0036. Procedure for the Management and Performance of Quality and Environmental Audits.

Indicators	Description
— Hours of training/worker	
— Personnel trained on safety (%)	
— Average number of courses per worker	
— Number of courses	
— Number of trainees attending	
— Duration of courses	
— Classroom hours	
— Hours–person	
— Training by areas/breakdown by courses	

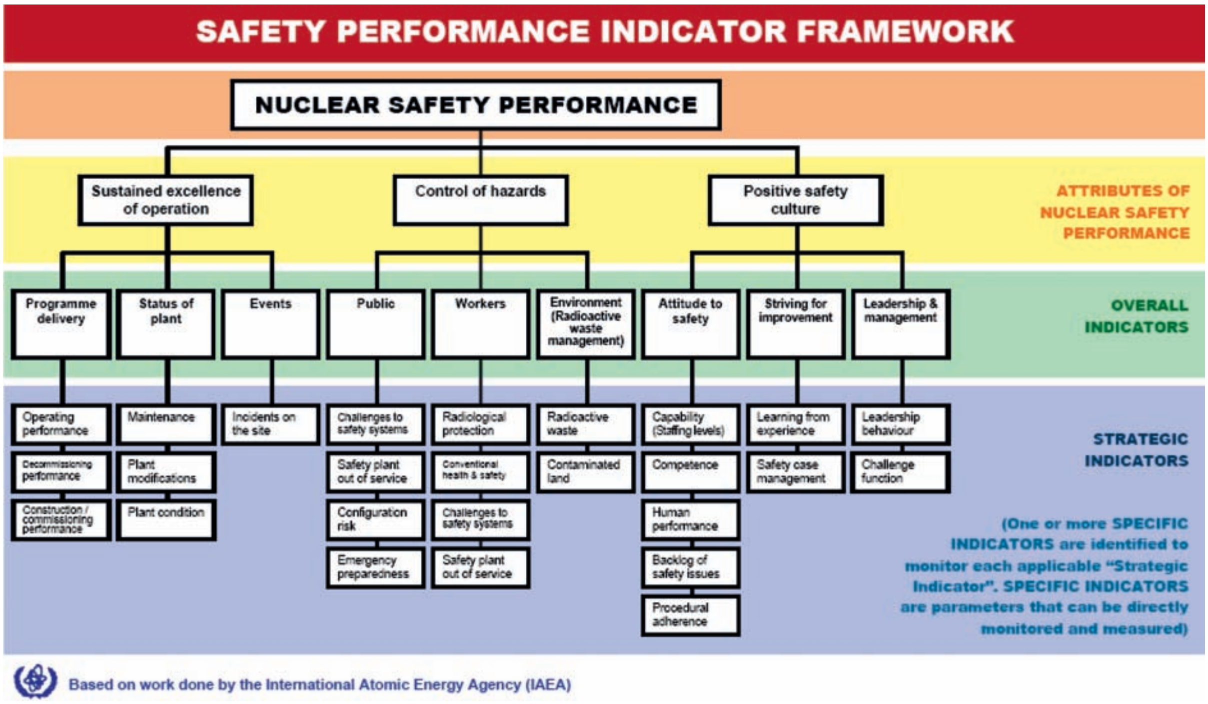


FIG. 1–E.1. Safety performance indicator framework used in the UK.

I–E.3. Licensees experience

All licensees in the UK use information from performance indicators as part of their management systems. In general, the scope of these performance indicators includes the areas of delivery of programmes of work, economics, environment and safety.

The development of performance indicators in UK high hazard industries has been influenced by the major incidents at British Petroleum (BP) Grangemouth in May–June 2000. The HSE/Scottish Environment Protection Agency (SEPA) report on these incidents [I–E.4] identified key lesson 2 for major accident hazard sites, "Companies should develop key performance indicators (KPIs) for major hazards and ensure process safety performance is monitored and reported against these parameters".

This key lesson has been reinforced by Recommendation No. 7 from the Baker Panel Report [I–E.5], which was issued following the BP Texas City explosion on 23 March 2005.

In response to the BP Grangemouth incidents, guidance on developing process safety indicators has been developed [I–E.6].

Development of performance indicators in the UK nuclear industry has also been influenced by the work of the IAEA, and in particular the work in IAEA-TECDOC-1141 [I–E.7]. Although this considers safety performance indicators (SPIs) for operating nuclear power plants (NPPs), it introduces the general concept of a hierarchical framework for the development of a performance indicators system. This general concept has been widely embraced by licensees. An SPI framework for decommissioning NPPs has been developed [I–E.8] based on the principles in IAEA-TECDOC-1141. This framework is not currently being used, but the methods developed in Ref. [I–E.8] to generalize the IAEA-TECDOC-1141 framework for operating NPPs to decommissioning NPPs were applied by licensees and the NII to produce a hierarchical framework relevant to nuclear safety at any site (see Fig. I–E.1.)

Use of either the guidance in Ref. [I–E.6] or the framework in Fig. I–E.1 during selection of SPIs leads to comprehensive sets of SPIs that should help anticipate future safety performance issues in a wide range of areas. Further information relating to Fig. I–E.1 is provided in the later section dealing with NII experience.

The influences of the major incidents and the work based on IAEA-TECDOC-1141 allow to make a general conclusion, specifically that licensees involved in decommissioning are developing comprehensive sets of performance indicators that should help anticipate future performance issues in a wide range of areas. This is in contrast to relying on limited sets of performance indicators only, capable of identifying poor performance that has already occurred in a few restricted areas, such as conventional health and safety.

I–E.4. NDA experience

This section summarizes three topics. The first is government targets for the NDA. The second is Health, Safety, Security and Environment (HSSE) indicators. The third is indicators to monitor decommissioning performance.

Government targets for the NDA

To help understand the environment in which the NDA operates, this section will describe Government targets for the NDA.

NDA's sponsoring government department has been given a Departmental Strategic Objective (DSO) to manage energy liabilities effectively and responsibly [I–E.9].

In support of this, the NDA is required to "establish a safe, affordable, innovative and dynamic market for clean-up and decommissioning" I.E–9] and to ensure progress in tackling the civil nuclear liability in line with agreed end-states for the NDA's sites and delivering value for money through:

- A reduction of the risk associated with high hazards and ensuring radioactive waste continues to be put into a passively safe form;
- A reduction in UK civil nuclear liabilities at least in line with agreed and published NDA Business Plans;
- Delivering minimum value for money savings on costs equivalent to 3% per annum averaged over the three-year Comprehensive Spending Review (CSR) period.

HSSE Indicators

This section refers to HSSE indicators that NDA uses to contribute to its oversight of nuclear licensed sites, rather than the indicators that it uses to monitor its own HSSE performance.

Publicly available information is in the NDA Annual HSSE Report 2007/08 [I–E.10]. As explained in Ref. [I–E.10], "from its early days, the NDA specified a simple set of common metrics to provide an overview of nuclear safety, industrial health and safety, radiation protection, environmental protection and regulatory compliance on the nuclear sites".

Reference [I–E.10] recognizes that indicators alone cannot provide a full picture of performance, and defines the aims of the HSSE indicators:

- To monitor trends;
- To allow benchmarking against average industry figures;
- To a lesser extent, to allow comparison of performance between sites;
- To help identify where good performance can be shared between sites;
- To guide the attention of NDA's nuclear safety assurance managers.

Work is ongoing with licensees and the regulators to develop the set of HSSE indicators for future years.

Indicators to monitor decommissioning performance

As explained in the licensees' experience section, comprehensive sets of performance indicators are being developed that should help anticipate future performance issues in a wide range of areas. Taking Fig. I–E.1 as an example, a licensee may have one or more indicators to represent each of the applicable areas (e.g. 'Maintenance', 'Safety Plant out of Service', etc.). This section focuses on indicators to represent the 'Decommissioning Performance' area in Fig. I–E.1, since this is an important area specific to decommissioning.

Reference [I–E.11] addresses performance monitoring, reporting and reviews at NDA sites. Standard Earned Value Management System performance indicators such as Cost Performance Index and Schedule Performance Index are evaluated for all the NDA sites. These performance indicators are particularly useful for NDA to monitor programmes of work that it has agreed with licensees. Limitations of these performance indicators consist in the need to establish the relationship between these agreed programmes of work and ‘reduction in hazard’. However, work has been carried out in this area by both the NDA and the NII, as reported below.

NDA has developed a Safety and Environmental Detriment (SED) indicator, which is calculated for each facility and for areas of contaminated land. This forms part of NDA’s remediation work prioritization procedure. Full details are in Ref. [I–E.12], with further background in Ref. [I–E.13]. For facilities, SED is evaluated by taking into account five factors:

(1) Radiological hazard potential
(2) Chemical hazard potential
(3) NII facility descriptor
(4) NII waste uncertainty descriptor
(5) Ongoing environmental detriment.

(For contaminated land, two of these factors are replaced by slightly different factors.)

Factors 1 and 2 relate to the hazard, while factors 3, 4 and 5 relate more to the potential for their release. SED is therefore an indicator that is ‘risk informed’. As shown in Appendix 10 of Ref. [I–E.12], the variation of site SED with time provides a possible indicator of decommissioning performance.

Factors 3 and 4 above, and others within the NDA procedure, are taken directly from NII’s (the safety regulator’s) remediation work prioritization methodology, as described in Ref. [I–E.14]. NII has developed its own methodology mainly to ensure that the introduction of additional financial and political considerations of NDA’s national prioritization procedure do not unacceptably distort NII’s more focused prioritization based on underpinned safety criteria or lead to an inability for individual licensees to meet their health and safety duties. A joint NII/NDA paper has been produced that compares and contrasts the NDA and the NII methodologies for remediation work prioritization [I–E.15]. This comparison concludes that there is reasonable consistency between NDA and NII approaches to facility prioritization; hence, variation of NDA’s SED with time or NII’s ‘scores’ with time could be used to monitor decommissioning performance. More significant differences arise in relation to project benefits and the expected rate of progress. Thus, in simple terms, the issue is one of timing or rate of hazard reduction.

To progress in resolving these issues, NDA is developing a Value Framework [I–E.16] involving engagement with regulators. This framework considers hazard reduction and additional socio-economic factors. NII’s current work in this area is reported in the later section dealing with NII experience.

I–E.5. Regulators experience

Environment Agency (EA)

The EA has developed and is implementing improvement plans for regulated business sectors. These are known as sector plans and their purpose is to:

— Focus on the most significant risks and impacts that the sector poses to the environment.
— Deliver improvements in the sector’s environmental management and performance.
— Prioritize and target effort within and across sectors.
— Achieve, through cooperation with sectors, environmental benefits beyond those that can be achieved through regulation.
— Monitor progress in delivering environmental improvements, within and between sectors.

Monitoring progress in delivering environmental improvements is supported by environmental performance indicators.

Ref.[I–E.17] is the Sector Plan for the nuclear industry — the Nuclear Sector Plan (NSP) that was developed in discussion with the nuclear industry. Section 3 of Ref. [I–E.17] defines the eight initial principal objectives of the NSP:

(1) Reduce the consumption of natural resources.
(2) Minimize and manage solid wastes.
(3) Reduce discharges to air and water.
(4) Reduce greenhouse gas emissions.
(5) Develop site restoration and biodiversity action plans.
(6) Improve transparency, understanding and engagement between the EA, industry and other key stakeholders.
(7) Promote product stewardship and wider supply chain benefits.
(8) Work to risk-based regulatory and environmental management systems.

Section 4 of reference [I–E.17] explains the background behind each of these principal objectives and how each one contributes towards implementing the overall NSP. It also identifies performance indicators that will be used to assess progress in achieving the objectives. It should be noted that whilst most performance indicators in the NSP relate to the environmental performance of licensees, some relate to EA performance.

Reference [I–E.18] is the EA's latest environmental report, which describes the environmental performance in 2008, measured against the objectives and performance indicators set out in the NSP.

Nuclear Installations Inspectorate (NII)

All licensees (i.e. not just those civil licensees involved in decommissioning) are working with NII and the Defence Nuclear Safety Regulator on a licensee SPIs Pilot Programme. A joint industry/nuclear regulators steering group has been set up.

The purpose of this pilot programme is to develop coherent, consistent sets of licensee safety performance indicators for:

— Use by licensees to improve nuclear safety performance;
— Developing a shared licensee/regulator understanding of nuclear safety performance;
— Use by the nuclear safety regulators to assess (together with results of assessment, inspection, operating experience feedback (OEF) and other relevant inputs) licensees nuclear safety performance to inform regulatory intervention strategies;
— Developing improved measures of major hazard risk control and potentially a new Public Service Agreement for the nuclear sector.

The SPI framework arising from this Pilot Programme (Fig. I–E.1) has been discussed above. Indicators to represent this framework have been selected by following a five step process:

(1) Each licensee considered which areas, i.e. which strategic indicators, in Fig. I–E.1 are applicable and appropriate to their business, and produces a short rationale for those that are not.
(2) Each licensee proposed one or more candidate SPIs to represent each of the applicable and appropriate areas. Where possible, these were from the licensees existing metrics.
(3) NII qualitatively evaluated the candidate SPIs with the licensees. This was mainly carried out by considering how well the SPI represented the purpose statement of the Strategic Indicator, as described in Table I–E.1. Therefore, in terms of the IAEA criteria inRef. [I–E.19], qualitative SPI evaluation was mainly based on face validity.
(4) Each licensee considered new SPIs to represent applicable and appropriate strategic indicators where adequate candidate SPIs were not available following step 3.
(5) NII quantitatively evaluated the candidate SPIs with the licensees following collection of data for a suitable period.

TABLE I–E.1. PURPOSE STATEMENTS FOR THE AREAS (I.E. THE STRATEGIC INDICATORS) IN THE SAFETY PERFORMANCE INDICATOR FRAMEWORK USED IN THE UK

Strategic Indicator	**Purpose Statement**
Operating performance	To monitor actual plant performance compared to planned plant performance.
Decommissioning performance	To monitor progress of decommissioning preparations and actual progress compared to planned progress]
Construction/commissioning performance	To monitor actual progress of the construction and commissioning of the new plant compared to planned plant performance (excluding the plant for radioactive waste management and decommissioning).
Maintenance	To monitor the maintenance of nuclear safety related plant, including significant results, to ensure that the status of plant is adequate.
Plant modifications	To monitor modifications on nuclear safety related plant, to help ensure they are adequately controlled so that the status of plant is adequate.
Plant condition	To monitor the condition of nuclear safety related plant, to help ensure that it is adequate.
Incidents on the site	To monitor all events recorded under LC 7 arrangements.
Public — challenges to safety systems	To monitor challenges to nuclear safety systems, to help ensure that these are minimized.
Public — safety plant out of service	To monitor the unavailability of nuclear safety plant, to help ensure that it is minimized.
Configuration risk	To monitor the ability to manage equipment out of service so that the risk is controlled at all times.
Emergency preparedness	To monitor the ability to protect the public if a radioactive release occurs.
Workers — challenges to safety systems	To monitor challenges in worker safety systems and to help ensure that they are minimized.
Workers — safety plant out of service	To monitor the unavailability of safety plant to protect workers, to help ensure that it is minimized.
Radiological protection	To monitor the ability to protect workers from ionizing radiation.
Conventional health and safety	To monitor the ability to protect workers from conventional health and safety hazards.
Radioactive waste	To monitor the management of radioactive waste on-site, including forward planning, progress with waste treatment (in particular, passivation and hazard reduction) and waste minimization.
Contaminated land	To monitor progress with planning, characterization, control and remediation of radioactively contaminated land.
Capability (staffing levels)	To monitor the ability to keep human resources to a level consistent with nuclear safety needs (LC 36).
Competence	To monitor the ability to ensure sufficient staff competence to deliver nuclear safety functions.
Human performance	To monitor human errors that impact on nuclear safety.
Backlog of safety issues	To monitor the ability to respond to nuclear safety related needs in a timely manner.
Procedural adherence	To monitor adherence to procedures that may affect nuclear safety.
Learning from experience	To monitor the effectiveness of the operating experience feedback process.

TABLE I–E.1. PURPOSE STATEMENTS FOR THE AREAS (I.E. THE STRATEGIC INDICATORS) IN THE SAFETY PERFORMANCE INDICATOR FRAMEWORK USED IN THE UK (cont.)

Strategic Indicator	Purpose Statement
Safety case management	To monitor the ability of the safety case management process to produce good quality safety cases first time and to actively maintain them.
Leadership behaviour	To monitor the attention to nuclear safety at the senior management level.
Challenge function	To monitor the effectiveness of nuclear safety related challenges at the senior management level.

To date, this quantitative evaluation has only been performed for one licensee not involved in decommissioning. It was based on the IAEA criteria in Ref. [I–E.19]. Following this step, agreed corrective actions will be implemented by licensees to improve SPIs for criteria where the score is low.

Figure I–E.2 shows the SPIs currently being trialled during the Pilot Programme by Magnox South Limited. This licensee is defuelling or decommissioning five Magnox sites. (Magnox North Limited has the same SPIs for the three Magnox sites that it is defuelling or decommissioning, but a modified set for the two Magnox sites that are still operating.)

The NII is currently incorporating the SPIs into its regulatory review process. Steering Group licensees are sharing experience of the SPIs being used during the Pilot Programme to spread good practice via the joint industry/nuclear regulators.

The NDA experience section describes indicators to monitor decommissioning performance. This section includes a description of some of the NII work in this area, and also notes that work is ongoing to reach a consensus view on timing or rate of hazard reduction. Additional relevant work is described next.

One of the licence conditions (LCs) attached to a nuclear site licence is LC 35 ‘Decommissioning’. This requires each licensee to have a decommissioning programme. Magnox North Limited and Magnox South Limited have recently developed improved arrangements for compliance with LC 35, which include maintaining a living, justified LC 35 decommissioning programme. The programme is represented by a series of ‘LC 35 decommissioning milestones’, which are generally key points corresponding to significant hazard reduction. Indicators are being developed that monitor progress in relation to LC 35 decommissioning milestones. There is an ongoing debate in this area on the health and safety duties of individual licensees in an environment in which NDA have duties across a range of licensees.

I–E.6. Summary

This national annex has summarized experience in the UK in relation to the selection and use of performance indicators in nuclear decommissioning.

The experiences of licensees, the NDA and selected regulators have been described.

A factual summary of key work has been provided, including references to more detailed information.

The influences of major incidents in the UK and the USA, and of the work in IAEA-TECDOC-1141 [I–E.7] has led to licensees developing sets of performance indicators that should help anticipate future performance issues in a wide range of areas.

Both the NDA and the regulators have responsibilities that encompass a significant number of licensees. These organizations are all using performance indicators to inform their oversight activities at the levels of both individual licensees and groups of relevant licensees.

For the NDA and the EA a set of licensee performance indicators has been selected that are common across relevant licensees. For the NII, a framework has been developed with licensees based on IAEA-TECDOC-1141 that is applicable to any licensee — see Fig. I–E.1. While the framework is common, different licensees may use different performance indicators to represent the applicable areas (i.e. the applicable ‘strategic indicators’) of the framework.

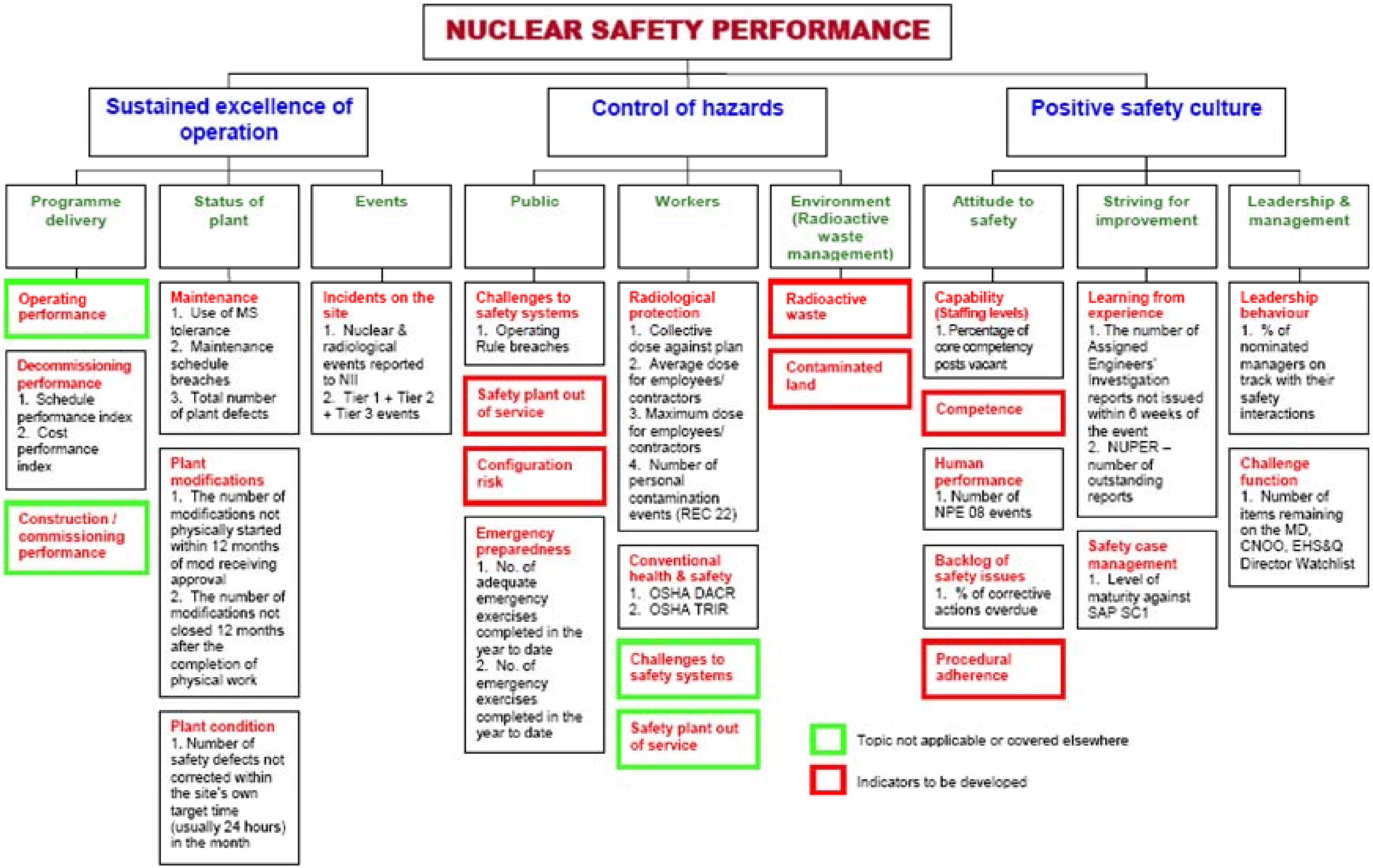


FIG. I–E.2. Example pilot programme safety performance indicators for reactor decommissioning.

One area in Fig. I–E.1 that will always be applicable to licensees involved in decommissioning is ‘Decommissioning Performance’. The work of licensees, the NDA and the NII to develop indicators to represent this area has been described.

REFERENCES TO ANNEX I–E

[I–E.1] UK NUCLEAR DECOMMISSIONING AUTHORITY, Strategy (Mar. 2006), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=4957.

[I–E.2] UK HEALTH AND SAFETY EXECUTIVE, The Licensing of Nuclear Installations (Mar. 2007), http://www.hse.gov.uk/nuclear/notesforapplicants.pdf

[I–E.3] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Document No. NSG 31 Rev 2 NDA Operating Model: The Roles of the Site Licence Company and the Parent Body Organisations (Jan. 2007), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=9980

[I–E.4] UK HEALTH AND SAFETY EXECUTIVE, Major Incident Investigation Report BP Grangemouth Scotland (29 May–10 June 2000), http://www.hse.gov.uk/comah/bpgrange/execsumm/lessons.htm

[I–E.5] US CHEMICAL SAFETY BOARD, The Report of the BP US Refineries Independent Safety Review Panel (Jan. 2007), http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/SP/STAGING/local_assets/assets/pdfs/Baker_panel_report.pdf.

[I–E.6] UK HEALTH AND SAFETY EXECUTIVE, HSE Document HSG254, Developing Process Safety Indicators, A Step-by-Step Guide for Chemical and Major Hazard Industries (Sep. 2006), http://www.hse.gov.uk/pubns/priced/hsg254.pdf.

[I–E.7] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Safety Performance Indicators for Nuclear Power Plants, ISSN 1011-4289, IAEA-TECDOC-1141, IAEA, Vienna (2000), http://www-pub.iaea.org/MTCD/publications/PDF/te_1141_prn.pdf

[I–E.8] ATKINS, Document No. 5044859-R-01 Issue 2, Safety Performance Indicator Framework for Decommissioning Nuclear Power Plants, November 2006.

[I–E.9] UK NUCLEAR DECOMMISSIONING AUTHORITY, Draft Business Plan 2009/2012, http://www.nda.gov.uk/documents/upload/Draft-Business-Plan-2009-to-2012.pdf.

[I–E.10] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Annual Health, Safety, Security and Environment Report (2007–2008), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=21886.

[I–E.11] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Document No. PCP13 Rev. 1. Baseline Management System — Performance Reporting and Reviews (Mar. 2007), http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=9257

[I–E.12] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Document No. EGPR02 Rev. 4 NDA Prioritisation Procedure (May 2008), http://www.nda.gov.uk/documents/upload/EGPR02-NDA-Prioritisation-Procedure-Rev4.pdf

[I–E.13] WAITE, R., HUDSON, I.D., WAREING, M.I., Development of a National M&O Contractor Work Prioritisation Process and its Use as a Progress Measure for Nuclear Clean Up in the United Kingdom Paper 6452 presented to WM’06 Conference, Feb. 26–2 Mar. 2006, Tucson, AZ, USA, Waste Management Symposia Ltd.

[I–E.14] CONNOLLY, P., ADDISON, P., The Approach of the United Kingdom’s Nuclear Installations Inspectorate to Prioritisation of the Work Associated with Remediation of the UK’s Nuclear Liabilities. Paper 6463 presented to WM’06 Conference, Feb. 26–2 March 2006, Tucson, AZ, USA, Waste Management Symposia Ltd.

[I–E.15] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Document No. EGR006 Rev. 0., Joint NII/NDA Paper Exploring Comparisons between their Respective Methodologies for Work Prioritization, http://www.nda.gov.uk/documents/upload/egr006_joint_nii_and_nda_paper_exploring_comparisons_and_contrasts_between_their_respective_methodologies_for_work_prioritisation_feb_2006.pdf.

[I–E.16] UK NUCLEAR DECOMMISSIONING AUTHORITY, NDA Document NSG63. Prioritisation, Hazard Baseline, and the Development of the Value Framework UPDATE ONLY, http://www.nda.gov.uk/documents/upload/NSG63-Briefing-Paper-on-Prioritisation-Hazard-Baseline-and-Development-of-Value-Framework-for-National-Stakeholder-Group-May-2008.pdf

[I–E.17] UK ENVIRONMENT AGENCY, Improving Environmental Performance, Sector Plan for the Nuclear Industry, http://publications.environment-agency.gov.uk/pdf/GEHO1105BJVE-e-e.pdf?lang=_e

[I–E.18] UK ENVIRONMENT AGENCY, Nuclear Sector Plan, 2008 Performance Report (Dec. 2009), http://www.environment-agency.gov.uk/static/documents/Business/GEHO1209BRRW-E-E_(2).pdf

[I–E.19] INTERNATIONAL ATOMIC ENERGY AGENCY, Development and Implementation of Safety Performance Indicators for Nuclear Power Plants, Safety Reports Series, IAEA, Vienna (2010).

I–F. EXPERIENCE AND OBSERVATIONS ON THE USE OF PERFORMANCE INDICATORS IN NUCLEAR FACILITY DECOMMISSIONING WITHIN THE U.S. DEPARTMENT OF ENERGY

I–F.1. Introduction

The Office of Environmental Management (EM) within the U.S. Department of Energy (DOE) conducts decommissioning projects for a comprehensive, wide variety of nuclear facilities. The variations among these facilities include their missions, design, age, type of construction, types and intensity of radiation and contamination, among many other factors. As a result, almost every project for a decommissioning a major facility has unique aspects, and in many cases require one-of-a-kind or first-of-a-kind engineering and operational solutions.

In the decommissioning field in the United States, the use of performance indicators has only formally become commonplace in the last ten years. This is mainly a result of some large nuclear sites undergoing final closure and the structuring of the contracts for completion of this work. The contracts were structured around meeting certain milestone completion dates under accelerated cleanup/decommissioning schedules. In some cases, the innovative approach has been taken to use performance indicators to monitor the work of individuals under contract who are rewarded or receive incentives to complete their work .

The use of performance indicators makes the process of a contractor’s work more formal in the approach that must be taken — no longer is it just the project manager’s estimate of the percentage of the activity done or of the progress in the removal or demolition process — there now are agreed quantitative goals or milestones for the work. Examples include: a certain number of waste packages that should be disposed of at a disposal site in a certain period of time; a certain number of facilities that must be demolished at the project site; or a date set for completion of a specified quantity of nuclear material. Typically, the more involved and complex the project, the more performance indicators may be needed to undertake the work and gauge its progress. This approach was used on many of the large DOE site closure projects that have been underway in the United States over the last ten years. The same approach can also be used for smaller projects — albeit a smaller number of measures: this is another example of the use of the ‘graded approach’ concept. Ref. [I–F.1] provides an example of how some contractors integrate performance indicators into their conduct of operations at some DOE sites, many of which now have significant decommissioning activities underway.

Much of the DOE’s performance measurement methods are not unique to decommissioning. Overall performance of a project is managed using conventional project controls systems with standard planning and tracking parameters such as scope definition, schedule tracking, costs (together with the ‘basis-of-estimate’ that defines the assumptions for the cost estimate), deviations of schedule and cost, and earned value systems. (These methods are addressed elsewhere in this report as applied to decommissioning and therefore are not discussed further.)

In addition, DOE has established systems and guidance for performance indicators that specifically address decommissioning programmes, projects and activities. Three are described below:

— Environmental Management Cleanup Projects Guidance
— Project Definition Rating Index
— Safety Occurrence Reporting.

I–F.2. Environmental Management Cleanup Projects guidance document

The Environmental Management Cleanup Projects is a guidance document that, among other subjects, addresses the methods for measuring work progress of the DOE’s environmental cleanup programme. The guidance complements the DOE’s internal regulation for overall project management. One major purpose of the guidance is to address the differences between decommissioning and new construction projects; the need arises because the principles of the primary directive are based on new construction project planning. The guidance document can be found at Ref. [I–F.2].

The guidance addresses many subjects, including performance parameters, addressed at two levels and discussed below. The first level relates to the overall organization. The individual results among all projects applicable to any specific category of performance are summed up to obtain overall organization performance.

The second level of performance relates to individual projects. The guidance addresses project types ‘Deactivation and Decommissioning’, ‘Soil and Groundwater Remediation’ and ‘Stabilization and Disposition’. For purposes here, only the first is discussed below as “Decommissioning” project performance.

The metrics listed in Table I–F.1 are corporate performance metrics. The specific performance metrics in the second column are described more fully in Ref. [I–F.3].

The guidance also addresses performance metrics for D&D projects with general descriptions of ‘End Points Specifications’, ‘Work Sets’ and ‘Quantitative Metrics’. The latter refers to units of measure described elsewhere in this report and are not repeated here. The first two are described below.

(i) End Points Specification

The end points method is a process for specifying the conditions to be achieved for a D&D project. Initiated during the Three Mile Island cleanup in the 1980s, the method was adapted and refined for DOE projects in the 1990s as a systematic way to specify facility deactivation.

The primary value of the end points method is that it systematically lists all the systems, major equipment and spaces within and external to the facility; and for each specifies the conditions to be achieved at the end of the deactivation phase of a D&D project that precedes demolition. It is important to understand that an end point specifies what is to be achieved, but not how. Once the conditions to be achieved are specified, how to reach the condition is left to those conducting the project. Table I–F.2 lists criteria when deriving end points for the deactivation phase of a decommissioning project. These criteria are applied to the end state configuration, whose examples at project completion include:

TABLE I–F.1. DOE ENVIRONMENTAL MANAGEMENT CORPORATE PERFORMANCE MEASURES DEFINITIONS

Category	Performance Metric Units
Plutonium, metal or oxide package for long term storage	Number of canisters
Enriched uranium packaged for long term storage	Number of containers
Material access areas eliminated	Number of areas
Plutonium or uranium residues packaged for disposition	Kilograms of bulk materials
Transuranic waste dispositioned	Cubic metres
Depleted and other uranium packaged for disposition	Metric tonnes
Spent nuclear fuel packaged for final disposition	Metric tonnes of heavy metal (MTHM)
High-level waste packaged for final disposition	Number of containers
Liquid waste in inventory eliminated	Kilo gallons
Liquid waste tanks closed	Number of tanks
Low-level and mixed low-level waste disposed	Cubic metres
Remediation completed	Number of remediation completions
Nuclear facility completed	Number of facilities
Radioactive facility completed	Number of facilities

TABLE I–F.2. DEACTIVATION END POINTS CRITERIA

Criteria Subjects	Criteria Statements
Structural and Boundary Integrity	Structural and boundary integrity will be such that: (a) Surveillance & Maintenance (S&M) and D&D personnel are safe, (b) contamination or hazardous materials remaining in the facility are contained or have been stabilized against release, and (c) intrusion by unauthorized personnel, animals and plants are prevented.
Nuclear Materials	Accountable nuclear material has been removed.
Hazardous Materials	Hazardous materials and chemicals have been removed in compliance with environmental regulations. Any hazardous materials remaining in the facility are labelled and confined or have been stabilized to prevent release. Documentation of quantities and location of remaining hazardous materials is complete.
Operational Systems and Equipment	Service and utility systems and equipment required to support S&M and maintain stable conditions (such as lighting, exhaust ventilation, sump pumps, etc.) are operational. Equipment that has been judged to be essential for future S&M or D&D (such as cranes or jib hoists) remains operational.
Abandoned or Removed Systems and Equipment	Non-essential systems and equipment have been: (a) abandoned in place and isolated, vented, and/or sealed, or (b) removed.
Personnel Safety	The safety of S&M and D&D personnel are safeguarded by stable conditions, postings and written procedures that have been established in accordance with standard procedures for radiological protection and industrial safety practice. Contamination remaining in the facility is clearly identified and has been stabilized.
Waste	Removable wastes have been disposed. The only liquid wastes remaining are minimal quantities within installed equipment that cannot be readily removed.
Housekeeping	Classified and valuable materials are removed. Trash, furniture and other loose equipment and materials have been removed.
Administrative	Facility specific records and documents have been transferred. This includes, for example, the Safety Basis, other regulatory requirements (such as permits), contracts, purchase orders and other agreements. Reporting requirements are identified. Government owned capital assets are listed.
Characterization	Data for as-left materials and conditions that are important to S&M and future D&D have been recorded and are retrievable.

— Internal rooms and spaces that will be accessible for human entry;
— Internal rooms and spaces that will not be accessible for human entry;
— Ancillary and other structures external to the main buildings;
— Systems and equipment that will remain operational;
— Systems and equipment that will be abandoned in place or removed.

End points can also be specifications for demolition and in situ decommissioning projects. End points for deactivation or in situ decommissioning will generally be more elaborate than for demolition. Description of the end points method can be found at Ref. [I–F.4].

The primary value of the end points method is that it systematically lists all the systems, major equipment and spaces within and external to the facility; and for each specifies the conditions that will define the deactivated state. It is important to understand that an end point specifies what is to be achieved, but not how. Project leaders determine how to achieve the conditions once specified.

An additional development by EM is the extension of the end points to administrative conditions in addition to physical ones. Administrative end points mostly specify records that are to be created and/or archived at the completion of the project.

TABLE I.F–3. EXAMPLES OF WORK SETS BY TITLE

Work Set Titles	
Remove water pipes	Deactivate fire annunciation
Remove electrical attached to shield blocks	Isolate domestic water (& fire main)
Remove roof shield blocks	Isolate sanitary drains
Roof blocks	Relocate drain monitoring and pumping sump
Remove wall blocks	Abate asbestos building 1
Remove inner roof blocks	Remove equipment and switchgear building 1
Remove and ship depleted uranium and lead from within shield blocks	Remove catwalk cables quadrant 1
Survey, package and ship other materials	Remove transite group 1
Gap power cables to the accelerator	Demolish cooling tower/basin/outside equipment
Remove west tangent tank and associated equipment	Demolish office area
Remove yoke assemblies and associated equipment	Demolish slab, tunnels, foundations for building 1
Remove ventilation duct equipment	Fill deep tunnel
Gap the electrical power to building	Backfill the building excavation

(ii) Work sets approach

The ‘work sets’ approach for building cleanout was successfully used at the Rocky Flats project for planning the process equipment dismantlement. ‘Sets’ were groupings of equipment typically in the same room or portion of a room that would be worked as a unit. The sets were area based, in contrast to activities defined by labour loading, such as removing runs of process piping that crossed several areas. Sets are defined by physical boundaries, physical quantities, and in some cases, by completion of administrative packages. For example, if a specified work set is ‘when a room in a building has been abated for asbestos and other hazardous materials’, the set is complete when the abatement completion criteria are satisfied. Additional discussion can be found at Ref. [I–F.5].

Project and a percentage of project progress are assigned in advance to each set; the percentage will vary among the work sets. The status of project completion is compiled by combining the status of completion among the entire population of work sets. This approach is highly useful when progress metrics are not constrained by the sequence in which the work is accomplished. It is also useful where the overall project milestones are controlled by funding limitations that cause the work schedule to be drawn out. In these cases, what matters is tracking the cumulative work sets completion on a month to month and milestones basis. Table I–F.3 contains some examples of work set titles used to plan the decommissioning of a large accelerator.

I–F.3. Project definition rating index

EM’s decommissioning projects are independently reviewed at two or three stages as the project progresses. (The number and frequency of reviews is dependent on the magnitude and complexity of a project.) Reviews are systematically conducted using EM’s Project Definition Rating Index (EM-PDRI). The EM-PDRI is a modified version of a commercially developed planning tool that examines a wide range of project factors related to cost, scope and schedule, and develops a numerical score as a measure of how well these factors are defined. The manual for this system can be found at Ref. [I–F.6]. It must be noted that although this manual presents a quantitative system for arriving at ratings, it is not uncommon to use it as guidance for what to review without necessarily applying the grading approach.

EM project types in the manual include ‘Conventional’, ‘Environmental Restoration’ and ‘Facility Disposition’. The latter is functionally equivalent to decommissioning projects. The five EM-PDRI categories for conducting a rating include cost, schedule, scope/technical, management planning and control, and external factors. Within each category are a number of rating elements; the number can vary depending on the type of project. For the purpose here, which is to identify performance indicators for decommissioning, the rating elements for disposition projects are listed in Table I–F.4.

TABLE I–F.4. EM-PDRI RATING ELEMENTS FOR DECOMMISSIONING SCOPE AND TECHNICAL CATEGORY

Rating Element	Rating Criteria
Alternatives Analysis/End State	Major alternatives are identified and viable alternatives are analysed. Alternative analysis includes comparisons of life cycle cost, feasibility (including Technology Development requirements), stakeholder values, safety, regulatory compliance and other factors as appropriate. The preferred option(s) is identified and justified. The intended overall condition and status of the facility at project completion (end state) is established.
Waste Characterization/Assess Current Situation	Waste and materials (if present) are sufficiently characterized to identify appropriate disposition alternatives. Soil samples have been taken and evaluated to identify presence of any hazardous substances (both radiological and chemical). Necessary plans and actions have been taken to confirm conditions, prepare documents and perform the discovery action, including resolving surveillance and monitoring activities, and safety considerations.
Trade-Off / Optimization Studies	The trade-off studies are performed as needed to reach a reasonable level of project risk consistent with project phase and overall project cost/schedule. These trade-off studies are a part of conceptual and later design phases to optimize the design of the selected alternative. The studies include alternative requirements and controls, and optimization approaches with consideration of technical safety requirements.
End Point Criteria	End point criteria have been defined, documented and approved for spaces, systems, materials and wastes, consistent with meeting the established end state for the project.
Functional and Performance Requirements	The project basis is developed and reviewed, and the appropriate level of approval is received from users, key stakeholders, site management and the DOE Programme Office. The project basis is also subject to peer review by appropriate technical experts in all major disciplines involved in project and resulting comments considered in the design basis.
Technology Needs Identified	The availability of new technology for project is evaluated, including benefits and risks. Technology development requirements for each alternative are documented.
Technology Needs Demonstrated	New technology is tested and determined to meet project objectives (technical, cost and schedule). The maturity of new technology to be used on project is evaluated and factored into risk analysis.
Hazard Analysis	The hazard analysis is completed and reflected in the final design. It addresses all significant risks (chemical, nuclear/radiological, industrial, etc.) associated with the project as well as the operation of the completed project.
Hazard Classification	The hazard classification is defined, completed and approved. Results are incorporated in technical baseline.

TABLE I–F.4. EM-PDRI RATING ELEMENTS FOR DECOMMISSIONING SCOPE AND TECHNICAL CATEGORY (cont.)

Rating Element	Rating Criteria
Safety Documentation	The required nuclear and chemical safety documentation is complete and approved in accordance with DOE orders. The safety analysis required input is completed, and requirements are developed together with the design, and proper considerations for the safety envelope are ‘designed in’. Comments are resolved and the results are incorporated into the necessary design documentation in support of Safety Documentation.
NEPA Documentation	NEPA activities, including NEPA strategy and requirements, are completed and compliant with DOE Orders, as necessary.
ES&H Management Planning (including ISMS)	Environmental, safety and health (ES&H) requirements as delineated in federal, DOE, state, site, and local laws and regulations are included in the facility and process design requirements. Any exceptions to ES&H requirements are documented, justified and approved. Integrated Safety Management System (ISMS) implementation is fully planned in accordance with DOE Orders. Safety plans for integrating safety management including fire, occupational, radiological, hygiene, etc. are completed, thorough and an integral part of the disposal effort. The requirements, methodology and responsibility for various ES&H activities are clearly communicated.
Safeguards and Security	The security approach and the potential requirements are documented to aid in development of safeguard and security plan. Safeguard and security requirements are identified, documented, and incorporated into detailed design drawings and specifications.
Emergency Preparedness	Specialized issues and considerations for emergency preparedness are adequately identified and documented. Emergency preparedness planning is complete for the disposition effort, and post-disposition emergency planning has been initiated. This planning has been coordinated with site and external response organizations, as appropriate.
Plot Plan	The preliminary plot plan is complete and shows the location of the project in relation to adjoining facilities.
Disposition Plans and Procedures	The project strategy addresses critical issues for transitioning from operations to disposition and from one disposition phase to another.
Site Characterization (Including Surveys and Soil Tests)	The assessment of site-specific requirements is completed. Survey and soil test evaluations of proposed site are completed. Investigation and development of site-specific characteristics are sufficient to support final design, and key assumptions are clearly documented. For example, limited soil borings (or samples) may have been taken.
Long Lead/Critical Equipment and Materials List	All engineered equipment and/or materials are fully specified, bid, and tabulated as necessary to support project schedule.
Work Package Completion	The work package documentation is completed including field instructions and requirements. Back-up files may include engineering files, trade-offs and calculations, etc.
Interface Planning and Control	System interfaces (consistent with system design descriptions) have been identified and defined, and if necessary, an Interface Control Plan has been completed, approved and implemented.

TABLE I–F.4. EM-PDRI RATING ELEMENTS FOR DECOMMISSIONING SCOPE AND TECHNICAL CATEGORY (cont.)

Rating Element	Rating Criteria
Loading/Unloading/Storage Requirements	A list of requirements identifying raw materials to be unloaded and stored (e.g. storage requirements for generated wastes, products to be loaded along with their specifications, and material safety data sheets created; cranes, remote handling equipment, etc. for the conduct of disposition activities).
Waste Acceptance Criteria (WAC)	The on- or off-site waste acceptance criteria is documented, approved, and the requirements included into the design requirements for the project.
Waste Packaging	The waste packaging requirements are identified, documented and included into the project design. All outstanding modifications to requirements are addressed.
Transportation Requirements	Transportation requirements including nuclear and hazardous materials are identified and documented including both off-site and in-plant transportation, as well as methods and equipment (casks, overpacks, etc.) for receiving/shipping materials (e.g. rail, truck, air, marine).
Pollution Prevention and Waste Minimization	Detailed waste minimization/pollution prevention plan for the project is completed for the selected design/project scope. Describe and estimate costs for, and present the implementation plan for the design, disposition, and mitigatory features that will minimize wastes and prevent pollution. A detailed waste management plan describing quantity and type of wastes expected to be generated and plans for waste treatment, storage and disposal is completed.
Training Requirements	Training input and planning is developed. Disposition considerations and training requirements are defined, approved and incorporated as appropriate. Simulation, mockup facilities are defined and established as necessary.
Post-Disposition Monitoring Plan	The Post-Disposition Monitoring Plan is prepared, approved and ready for implementation by the performing organization.

I–F.4. Safety occurrence reporting

EM has an internal safety occurrence reporting system used for tracking, mapping, and providing alerts for events in the field performance among all of EM's projects in the field.

DOE's Occurrence Reporting and Processing System (ORPS) is a notification system to keep DOE management informed of various environmental, safety, security, or health-related events across the national complex of the DOE sites. ORPS is described in the Environment, Safety and Health Reporting Manual, USDOE M 231.1-2 [I–F.7].

The ORPS system includes a wide variety of safety indicators, many of which do not directly relate to decommissioning projects. Therefore, the EM has selected a set of safety indicators, shown in Table I–F.5, which are relevant to facility deactivation, cleanout and demolition activities.

The wealth of data collected in these occurrence reports is analysed monthly for common types of events, common causes of events, or trends of various characteristics. The monthly report for EM contains the following sections:

— A summary of the month's safety highlights that summarizes statistics, addresses trends, describes significant occurrences, and corrective actions being taken;
— A review of quarterly performance and analyses of recurring events;
— A report of safety indicators for each site;
— A report of safety performance by major contractors;
— A report of safety performance by safety indicator areas.

TABLE I–F.5. ENVIRONMENTAL MANAGEMENT OCCURRENCE REPORTING INDICATORS

Indicator Category	Subjects to be included
Authorization Basis	— Violation or failure to comply with of safety analyses and operational safety requirements.
Conduct of Operations	— Violation of general management administrative requirements.
Electrical Safety	— Failed or defective electrical wiring within components, power cords, extension cords, temporary low voltage power lines, receptacles, and plugs. Includes problems with phasing and grounding, as well as communication lines. — Failed electrical equipment and/or failed function for such as battery/battery chargers, circuit interrupting devices, transformers, motors, ultimate power supplies.
Environmental Releases/Compliance Violations	— Event where there was a release of radioactivity to the environment or release of hazardous materials to the environment. — Issues related to underground storage tank releases including leaks and failures. — Compliance Notification from an environmental regulatory agency with a violation)
Equipment Degradation/Failure	— Equipment failures, equipment over stressed or compromised.
Fatalities	— Fatalities while on the job.
Fire Protection and Explosive Safety	— Fire protection equipment degraded or inoperable fire protection system equipment, including detection and notification circuits. — Fire suppression actuation of an installed fire suppression system. — Fire/explosion — Explosives safety involving the failure to safely handle or store explosives or unstable/shock-sensitive chemicals. — Violation of National Fire Protection Association/Life Safety Code.
Industrial Operations	— Hoisting/rigging, forklift, drilling, construction/demolition, excavation and other material handling events using heavy equipment, e.g. procedures were not followed, out-of-date equipment used, improper hoisting, construction, excavation, or demolition activities.
Injuries	— Requiring off-site medical treatment
Lockout/Tagout (LO/TO)	— Violation of electrical or mechanical LO/TO procedure such as tags incorrectly applied and/or verified, prematurely removed, not filled out correctly, or tags not placed when required.
Near Miss	— Close calls for what could have been a serious injury or fatality because of luck electrically shocked, over-exposed to radiation, toxic gas or chemicals.
Nuclear	— Criticality safety concern.
Occupational Safety and Health	— Violation of work place safety practices and procedures; — Indoor air quality contamination related to radon, carbon monoxide, mould, fungi, spores, etc; — Industrial hygiene exposure; — Safety equipment failures.

TABLE I–F.5. ENVIRONMENTAL MANAGEMENT OCCURRENCE REPORTING INDICATORS (cont.)

Indicator Category	Subjects to be included
Radiological Control	— Radiological contamination of any clothing, shoes, hat; — Radiological contamination (fixed or removable) detected outside of controlled areas; — Inadequate job planning (RadCon); — Lack of Radiation Work Permit (RWP) when required, inadequate RWPs, failure to address all job related radiological control issues, or failure to conduct required surveys; — Inadequate radiological control training, lack of training, or missed refresher training.
Radiological Skin Contaminations, Uptakes, Overexposures	— Radiological contamination of skin and hair; — Confirmed intake/uptake from inhalation, ingestion, or injection; Any external over exposure.
Safeguards and Security	— Fitness for duty, involving use of drugs, alcohol, or controlled substances while on duty (substance abuse) or detected during random testing; — Material accountability issues that deal with radioactive source control or special nuclear material (e.g. nuclear material in an unexpected area or exceeding inventory limits); — General security issues not addressed elsewhere. Any events involving the misuse or accidental discharge of firearms by security or protection force personnel; — Theft/sabotage
Shipping	— Events involving a non-compliance with federal, state or local regulations (e.g. inadequate labelling or packaging, procedure non-compliance, or incorrect/missing MSDS); — Industrial equipment movements when not actually performing an industrial operation; — Notice of violation or non-compliance from local, state or federal agency; — Shipping incidents/accidents involving the transportation of DOE waste or material.
Suspect/Counterfeit Items — Defective Items	— Discovery of non-qualified parts or items that have evidence of tampering.
Vehicle Accident	— Vehicle accidents that involve DOE vehicles, employees, or on DOE property

The monthly report can typically contain as many as 30 trend charts and other graphic displays. An example is a statistical control chart shown below (Fig. I.F–1) for the ‘Near Miss’ indicator category in the preceding table.

The Statistical Control Charts show the data points for a given safety metric over time. These charts give the calculated fixed statistical starting mean and the standard deviations. Points below the mean are blue; above the mean and below 2 standard deviations is the green zone; between 2 standard deviations and 3 standard deviations is the yellow ‘warning’ zone; And above 3 standard deviations is the red ‘attention’ zone. Long periods of continuous green, or several spikes into the yellow or red strata, are cause for closer examination. Since data tend to fluctuate up and down due to random events, systemic trends are notable when there is a grouping of 6–9 points in one zone above or below the mean.

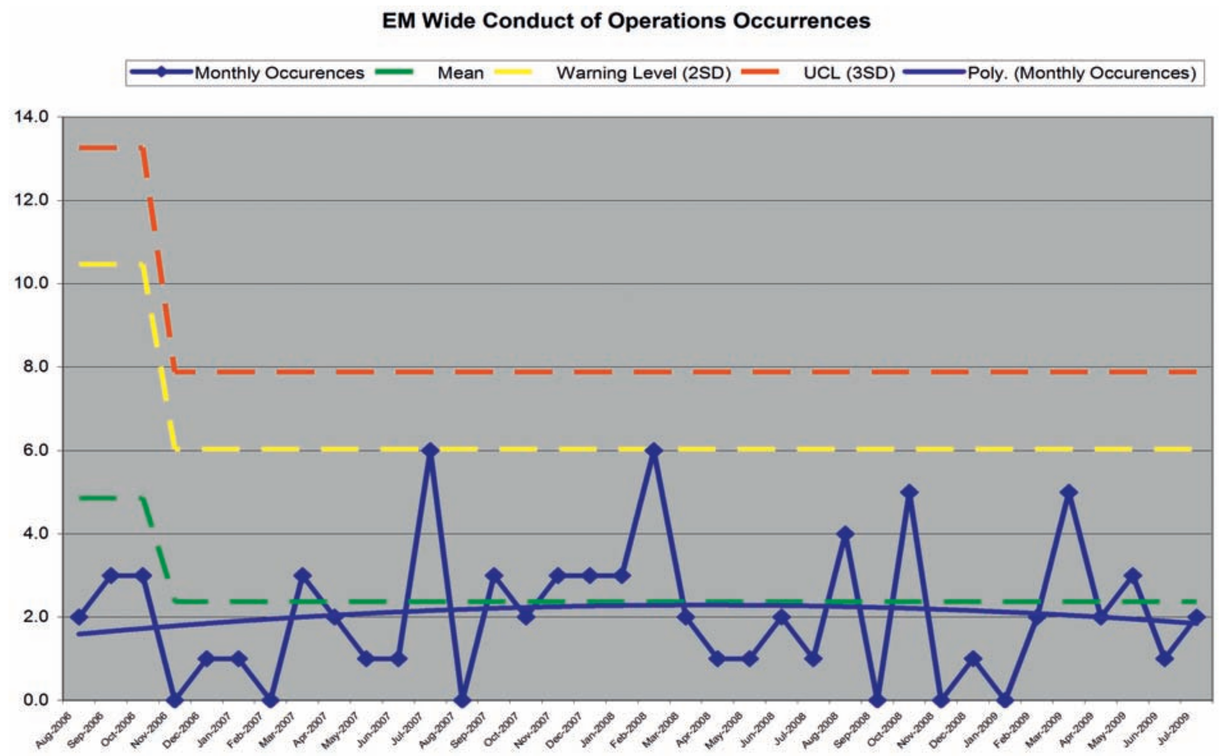


FIG. I–F.1. EM wide conduct of operations occurrences.

REFERENCES TO ANNEX I–F

[I–F1] Energy Facility Contractors Group, DOE Performance Metrics Reporting Process Point Paper Revision 2, EFCOG November 2002, web site, http://www.efcog.org/wg/ism/Pefrormance_Metrics_Info/DOE-PM%20Point%20Paper.pdf
[I–F2] US DEPARTMENT OF ENERGY web site, http://www.directives.doe.gov/pdfs/doe/doetext/neword/413/g4133-8.pdf
[I–F3] US DEPARTMENT OF ENERGY web site, http://www.em.doe.gov/Pages/perfmeasdef.aspx
[I–F4] US DEPARTMENT OF ENERGY web site, http://www.em.doe.gov/DandD/epman.aspx
[I–F5] US DEPARTMENT OF ENERGY web site, http://rockyflats.apps.em.doe.gov/chapters/08%20-%20Decommissioning.pdf
[I–F6] US DEPARTMENT OF ENERGY web site, http://www.em.doe.gov/pages/pdri.aspx
[I–F7] US DEPARTMENT OF ENERGY web site, http://www.directives.doe.gov/pdfs/doe/doetext/neword/231/m2311-1ac2.pdf

Annex II

CASE HISTORIES/EPISODES INVOLVING THE USE OF DECOMMISSIONING INDICATORS

The following examples of lessons learned outline the problems encountered at the nuclear facilities involved. The situations point out at occurrences denoting trends that can arise when implementing a decommissioning project, and can be viewed as performance indicators. Although the information is not intended to be exhaustive, the reader is encouraged to evaluate the applicability of the lessons learned to a specific decommissioning project.

CASE NO. 1. TREND ANALYSIS IDENTIFIES HOISTING AND RIGGING PROBLEM [II-1]

Problem encountered: Analysis of the number of hoisting and rigging occurrences at Hanford revealed a statistically significant increase in the number of events since October 1995. This increase was brought to the attention of the Hanford Hoisting and Rigging Committee for Action. Trending of hoisting and rigging occurrences is accomplished by searching the Occurrence Reporting and Processing System (ORPS) database for the following words: overload, overstress, pulley, lift, dynamometer, winch, forklift, hoist, crane, sling, rigging, hook, load block, or two blocks. The reports found in that search are reviewed to confirm that they actually relate to hoisting and rigging and do not merely contain one of those words (e.g. sewage ’lift’ station). The number of occurrences is plotted on control charts containing an average line and upper and lower three-standard-deviation control limits. The data should remain focused on the average and between the control limits if there are no statistically significant trends. From these plots, trends can be readily detected and brought to management attention. The review of the hoisting and rigging trend charts for data through April 1996 revealed that the numbers of events for seven months in a row were above the 0.54 reports per month historical average. This is indication of a statistically significant increase. This increasing trend and a summary of the 13 occurrences during the seven months were presented to the Hanford Hoisting and Rigging Committee, which is made up of representatives from each of the Hanford contractors. The Committee felt that a rash of forklift related incidents were responsible for the increase. They agreed that the trend required action, so they formed a special subcommittee to raise the visibility of forklift safety. The subcommittee drafted a Hoisting and Rigging Bulletin to address ’free rigging’ from forklifts.

Lesson learned: Proper analysis of easily obtainable data from the ORPS can be used to identify trends that may indicate a potential developing problem. Once a trend is identified, early and aggressive preventive measures can be implemented to remedy problems that might lead to a serious injury or death if left uncorrected.

CASE NO. 2. ANALYSIS OF PERFORMANCE DATA INDICATES AREAS RECOMMENDED FOR ASSESSMENT [II–2]

Problem encountered. In May 2004, Fluor Hanford (FH) Regulatory Compliance formed a diverse team to develop and implement a process for discovering and acting on potential adverse trends to guide future assessment planning efforts. The team adopted the name Quarterly Data Analysis Working Group (QDAWG) and developed a mission statement and the process. In developing a risk assessment process, they compared several risk assessment models from other DOE sites as well as other FH organizations to produce one that would work with their data analysis process. The team then applied the selected tools to performance data from the previous year. By analysing data for the previous year from various sources, including a deficiency tracking system (DTS), an authoritative source log, the Occurrence Reporting and Processing System and expert knowledge, the QDAWG identified several areas in which FH is potentially vulnerable. See the Recommended Actions section below.

Analysis: The Assessment Risk Model was the primary analysis tool used in the QDAWG process. The model includes consideration of time since last assessed, historical performance, importance of the activity, and other factors that may indicate a failure to meet requirements, expectations for safely performing the work, or FH goals. The model assigns weighting factors in each category and thus ranks the areas being analysed. As a final check on the model, the team applied a modified nominal group ranking technique to the final list to confirm their ranking.

Recommended Actions

The FH quality assurance organization initiated independent assessments during fiscal year 2005 in the following areas:

— Work Management
— Records Management Programme
— Training and Qualifications
— Packaging and Transportation
— Procurement Process.

The QDAWG recommends that Projects, Facilities, and supporting Functional Organizations assess the following areas on a priority basis in fiscal year 2005 through their management assessment programmes:

— Electrical Safety Programme
— Procedure Validation Process
— Job Hazard Analysis
— Document Control Process
— Human Factors (D&D).

Lessons learned: This lesson learned report explains the purpose of the Quarterly Data Analysis Working Group (QDAWG) and informs site personnel of the assessment recommendations derived from its process. The team analysed various sources of performance data for the previous year and determined that several areas should receive priority when scheduling independent and management assessments. See the “Recommended actions” section above for the proposed list of focus areas.

CASE NO. 3. USE OF PROBLEM EVENT REPORT (PER) PROCESS

Problem encountered: The Environmental Protection and Waste Services Division (EP&WSD) developed the Problem Event Report (PER) system in 2003 to provide a mechanism for documenting minor problems that did not fall under another reporting mechanism (e.g. non-conformance report, occurrence report). This system is implemented under a division level internal operating procedure and uses ORNL’s existing Assessment and Commitment Tracking System (ACTS) for data management. The system has been refined and expanded over the past few years, and now provides a comprehensive, easily accessible picture of all quality issues self-identified by the division. Fifty-nine PERs were documented in FY 2007. The PER system has proved extremely useful to our division for performance trending, and identifying emerging issues for resolution before they can become major deficiencies.

EP&WSD’s PER system was identified as a noteworthy practice during an ORNL Operational Awareness Program assessment conducted in November 2007.

Analysis: The PER system provides a mechanism for EP&WSD staff to identify, document, evaluate, segregate, disposition, and notify affected organizations and the Waste Certification Official (WCO), and track and trend quality and performance problems and issues (including opportunities for improvement and good practices) that arise during work activities. The PER process allows for the detection and prevention of quality problems, verification of conformance to specified requirements, and documentation of the performance of quality improvement processes.

Each PER is entered as an issue in ACTS, and appropriate actions are entered under each issue for tracking. All PERs are reviewed by the WCO for potential impact on the waste certification program, and the division Price-Anderson Amendments Act (PAAA) coordinator for PAAA reportability. This is achieved and documented through the independent reviewer and PAAA review mechanisms built into the ACTS software. The ACTS distribution field is used to communicate the issue to appropriate staff, including staff outside EP&WSD as appropriate (e.g., safety or radiological subject matter experts). While cause code selection is not required by the ACTS software for this is required by ISO 14001 and for division trending.

When a PER is initiated in ACTS for events or issues that will invoke additional and/or more stringent requirements than those imposed by the PER process (e.g. those for reportable events), the PER is used as a ‘placeholder’ to document the problem event and provide traceability to the higher level ORNL Standards Based Management System (SBMS) requirement(s) that govern it. PERS are also written to document events that impact EP&WSD but are owned by other organizations. The PER system therefore provides an easily accessible picture of all self-identified quality issues and improvement opportunities within EP&WSD.

EP&WSD Group Leaders review the PERs and associated actions generated by their group to determine if:

— Corrective actions are adequate to address the problem and prevent recurrence.
— Ongoing work needs to be stopped.
— The PER involves a significant issue adverse to quality or performance.

Prior to closing a PER, the Group Leader ensures that:

— All corrective actions are completed.
— Closure evidence is sufficient (includes the attachment of all available and applicable reports, emails, photographs, etc. to the ACTS record).
— PAAA and WCO reviews are completed and documented.
— Hold tags are removed, if applicable.

EP&WSD Group Leaders review their Group’s PER log (i.e. associated ACTS Assessment Tree) quarterly and at the end of the fiscal year to identify trends, items, services and processes that need improvement. The Group Leader verifies the adequacy of corrective actions identified to improve performance. As part of the quarterly review, EP&WSD trends all issues in ACTS (including PERs and issues identified during assessments) by cause code and cause code category. The PER process has enabled prompt identification of emerging trends, including issues involving packaging of waste in sealants and chemical safety issues. An annual PER trending report is issued at the division level, and PER programme results and conclusions are summarized in the Mid Year and End-of-Year Status Reports for the Environmental Management System.

A comparison of the results of the November 2007 OAP assessment of the Environmental Protection and Waste Services Division with the 2004 OAP assessment results demonstrates the dramatic improvement our Division has made in the areas of safety, environmental, radiological and work control. The total number of OAP findings was five in 2007, compared to 35 in 2004. This improement is due, in part, to the maturity of our PER system.

Lesson learned: A PER system for documenting self-identified issues (major and minor), opportunities for improvement, and good practices is a useful tool for trending performance, identifying emerging trends and encouraging continuous improvement.

CASE NO. 4. PRODUCTIVITY OF THE BOX COUNTER

Problem encountered: During the materials declassification or clearance process at Vandellós I NPP, the containers (packages) were subjected to characterization in a box counter, with the ultimate aim of cataloguing them (or not) as free from radioactivity. The schedule established that 25 such packages should be measured in each working day. The indicator ‘Register of Packages/Unit of Time’ indicated that, on average, only 15 measurements were being performed per day. In view of this deviation, the process was analysed and it was detected that the problem was not due to any malfunctioning of the box counter, but to the work involved in transporting, preparing and positioning each package in the measuring device.

Analysis: As the measuring time of the box counter could not be reduced, modifications were made to reduce the transport times, with the incorporation of a platform for the trucks, specific training for the drivers and the elimination of downtimes between measurements.

Lesson learned: Following productivity assessments, actions should not be based only on individual indicators, but require a careful analysis of circumstances.

CASE NO. 5: HIGH INDEX OF REJECTIONS IN THE DECLASSIFICATION OF MATERIALS

Problem encountered: In planning the dismantling of Vandellós I NPP, estimates were performed regarding the materials that would be open to declassification and therefore to treatment as conventional wastes. However, as the process got under way, the indicator 'percentage of rejection/packages measured' exceeded the calculations foreseen. The containers or packages rejected by the box counter had to be opened for inspection of each material to identify the anomaly. The analysis of these containers established that the high rate of rejection was due to a problem at the point of origin: the procedure used to prepare the materials packages/containers was imprecise regarding the homogeneity of the materials (in both their nature and their geometry) required by the box counter.

Analysis: The methodology was reinforced as the materials were deposited in the containers in accordance with rigorous specifications aimed at achieving homogeneity as regards the isotopic spectrum, the density of the elements, surface, etc. An operator now controls compliance with this method in the areas of origin of the containers.

Lesson learned: Performance indicators are strongly related to assessment procedures.

REFERENCES TO ANNEX II

[II–1] WESTINGHOUSE HANFORD CO., 1996-RL-WHC-0035, 6/20/1996 (available upon subscription to DOE database).

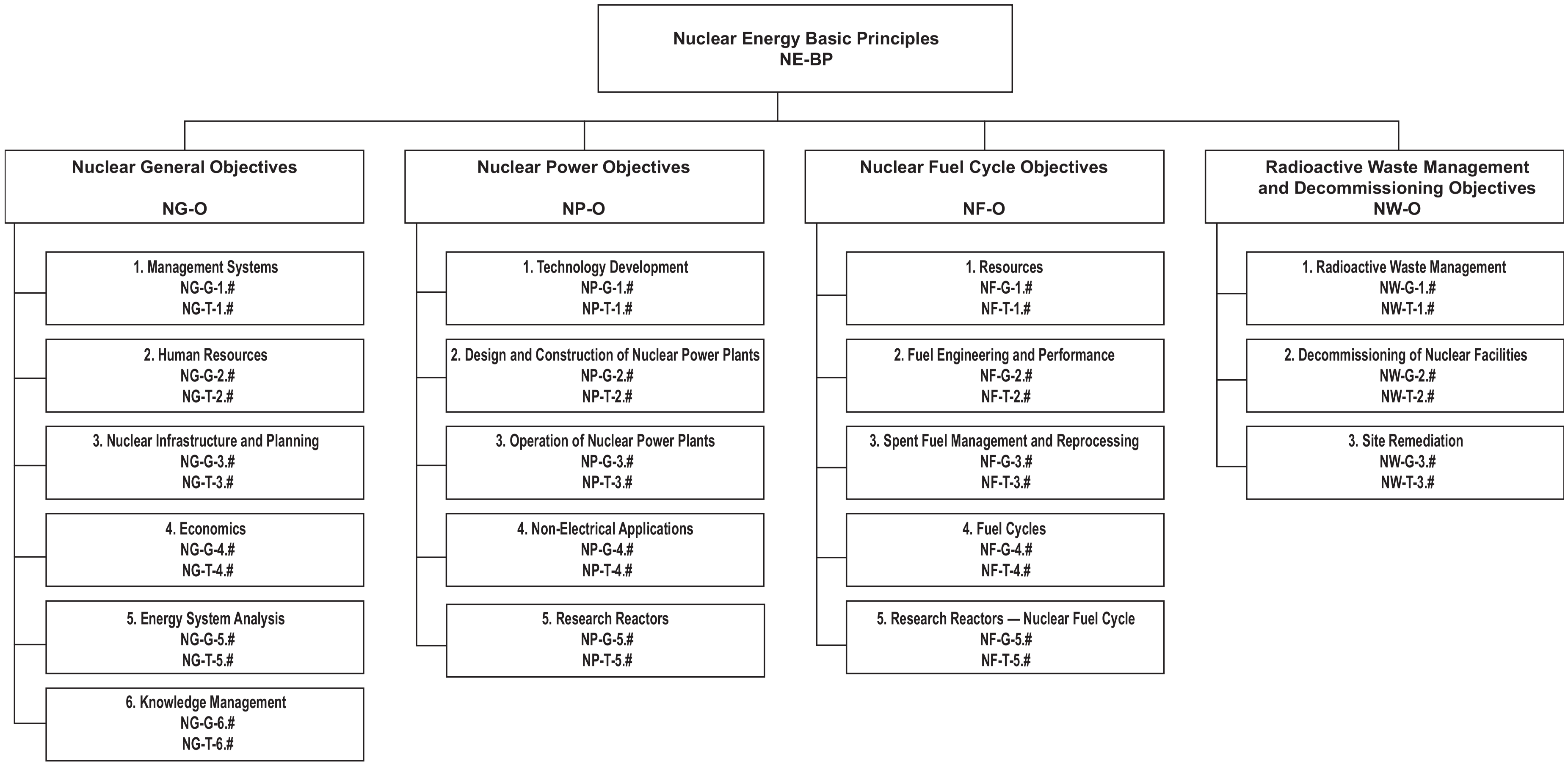
[II–2] FLUOR HANFORD, INC., 2004-RL-HNF-0039, 9/30/2004 (available upon subscription to DOE database).

[II–3] OAK RIDGE NATIONAL LABORATORY, 2008-UTB-ORNL-0008 (available upon subscription to DOE database).

CONTRIBUTORS TO DRAFTING AND REVIEW

Benitez-Navarro, C	Centre for Radiation Protection and Hygiene (CPHR), Cuba
Boing, L.E.	Argonne National Laboratory, United States of America
Green, V.R.	HM Nuclear Installations Inspectorate, United Kingdom
Hannan, A.M.	Private consultant, United Kingdom
Harriague, S.	Comisión Nacional de Energía Atómica, Argentina
Laraia, M.	International Atomic Energy Agency
Lauridsen, K.	Danish Decommissioning, Denmark
Llamero, L.L.	Empresa Nacional de Residuos Radiactivos (ENRESA), Spain
Martinez, R	Project Enhancement Corporation, United States of America
Maset, E.	Comisión Nacional de Energía Atómica, Argentina
Meyer, F.	Nuclear Engineering Seibersdorf, Austria
McIntyre, P.J.	Private consultant, United Kingdom
Negin, C.	Project Enhancement Corporation, United States of America
Sterner, H.	Energiewerke Nord, Germany
Stoev, M.	Kozloduy Nuclear Power Plant, Bulgaria

Structure of the IAEA Nuclear Energy Series



Key

BP: Basic Principles
O: Objectives
G: Guides
T: Technical Reports
Nos. 1-6: Topic designations
#: Guide or Report number (1, 2, 3, 4, etc.)

Examples

NG-G-3.1: Nuclear General (**NG**), **G**uide, Nuclear Infrastructure and Planning (topic **3**), **#1**
NP-T-5.4: Nuclear Power (**NP**), Report (**T**), Research Reactors (topic **5**), **#4**
NF-T-3.6: Nuclear Fuel (**NF**), Report (**T**), Spent Fuel Management and Reprocessing, **#6**
NW-G-1.1: Radioactive Waste Management and Decommissioning (**NW**), **G**uide, Radioactive Waste (topic **1**), **#1**

IAEA
International Atomic Energy Agency

Where to order IAEA publications

In the following countries IAEA publications may be purchased from the sources listed below, or from major local booksellers. Payment may be made in local currency or with UNESCO coupons.

AUSTRALIA
DA Information Services, 648 Whitehorse Road, MITCHAM 3132
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

BELGIUM
Jean de Lannoy, avenue du Roi 202, B-1190 Brussels
Telephone: +32 2 538 43 08 • Fax: +32 2 538 08 41
Email: jean.de.lannoy@infoboard.be • Web site: http://www.jean-de-lannoy.be

CANADA
Bernan Associates, 4501 Forbes Blvd, Suite 200, Lanham, MD 20706-4346, USA
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 1-5369 Canotek Rd., Ottawa, Ontario, K1J 9J3
Telephone: +613 745 2665 • Fax: +613 745 7660
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

CHINA
IAEA Publications in Chinese: China Nuclear Energy Industry Corporation, Translation Section, P.O. Box 2103, Beijing

CZECH REPUBLIC
Suweco CZ, S.R.O., Klecakova 347, 180 21 Praha 9
Telephone: +420 26603 5364 • Fax: +420 28482 1646
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

FINLAND
Akateeminen Kirjakauppa, PO BOX 128 (Keskuskatu 1), FIN-00101 Helsinki
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

FRANCE
Form-Edit, 5, rue Janssen, P.O. Box 25, F-75921 Paris Cedex 19
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: formedit@formedit.fr • Web site: http://www. formedit.fr

Lavoisier SAS, 145 rue de Provigny, 94236 Cachan Cedex
Telephone: + 33 1 47 40 67 02 • Fax +33 1 47 40 67 02
Email: romuald.verrier@lavoisier.fr • Web site: http://www.lavoisier.fr

GERMANY
UNO-Verlag, Vertriebs- und Verlags GmbH, Am Hofgarten 10, D-53113 Bonn
Telephone: + 49 228 94 90 20 • Fax: +49 228 94 90 20 or +49 228 94 90 222
Email: bestellung@uno-verlag.de • Web site: http://www.uno-verlag.de

HUNGARY
Librotrade Ltd., Book Import, P.O. Box 126, H-1656 Budapest
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472 • Email: books@librotrade.hu

INDIA
Allied Publishers Group, 1st Floor, Dubash House, 15, J. N. Heredia Marg, Ballard Estate, Mumbai 400 001,
Telephone: +91 22 22617926/27 • Fax: +91 22 22617928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell, 2/72, Nirankari Colony, Delhi 110009
Telephone: +91 11 23268786, +91 11 23257264 • Fax: +91 11 23281315
Email: bookwell@vsnl.net

ITALY
Libreria Scientifica Dott. Lucio di Biasio “AEIOU”, Via Coronelli 6, I-20146 Milan
Telephone: +39 02 48 95 45 52 or 48 95 45 62 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Website: www.libreriaaeiou.eu

JAPAN
Maruzen Company, Ltd., 13-6 Nihonbashi, 3 chome, Chuo-ku, Tokyo 103-0027
Telephone: +81 3 3275 8582 • Fax: +81 3 3275 9072
Email: journal@maruzen.co.jp • Web site: http://www.maruzen.co.jp

REPUBLIC OF KOREA
KINS Inc., Information Business Dept. Samho Bldg. 2nd Floor, 275-1 Yang Jae-dong SeoCho-G, Seoul 137-130
Telephone: +02 589 1740 • Fax: +02 589 1746 • Web site: http://www.kins.re.kr

NETHERLANDS
De Lindeboom Internationale Publicaties B.V., M.A. de Ruyterstraat 20A, NL-7482 BZ Haaksbergen
Telephone: +31 (0) 53 5740004 • Fax: +31 (0) 53 5729296
Email: books@delindeboom.com • Web site: http://www.delindeboom.com

Martinus Nijhoff International, Koraalrood 50, P.O. Box 1853, 2700 CZ Zoetermeer
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: http://www.nijhoff.nl

Swets and Zeitlinger b.v., P.O. Box 830, 2160 SZ Lisse
Telephone: +31 252 435 111 • Fax: +31 252 415 888
Email: infoho@swets.nl • Web site: http://www.swets.nl

NEW ZEALAND
DA Information Services, 648 Whitehorse Road, MITCHAM 3132, Australia
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

SLOVENIA
Cankarjeva Zalozba d.d., Kopitarjeva 2, SI-1512 Ljubljana
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: http://www.cankarjeva-z.si/uvoz

SPAIN
Díaz de Santos, S.A., c/ Juan Bravo, 3A, E-28006 Madrid
Telephone: +34 91 781 94 80 • Fax: +34 91 575 55 63
Email: compras@diazdesantos.es, carmela@diazdesantos.es, barcelona@diazdesantos.es, julio@diazdesantos.es
Web site: http://www.diazdesantos.es

UNITED KINGDOM
The Stationery Office Ltd, International Sales Agency, PO Box 29, Norwich, NR3 1 GN
Telephone (orders): +44 870 600 5552 • (enquiries): +44 207 873 8372 • Fax: +44 207 873 8203
Email (orders): book.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: http://www.tso.co.uk

On-line orders
DELTA Int. Book Wholesalers Ltd., 39 Alexandra Road, Addlestone, Surrey, KT15 2PQ
Email: info@profbooks.com • Web site: http://www.profbooks.com

Books on the Environment
Earthprint Ltd., P.O. Box 119, Stevenage SG1 4TP
Telephone: +44 1438748111 • Fax: +44 1438748844
Email: orders@earthprint.com • Web site: http://www.earthprint.com

UNITED NATIONS
Dept. I004, Room DC2-0853, First Avenue at 46th Street, New York, N.Y. 10017, USA
(UN) Telephone: +800 253-9646 or +212 963-8302 • Fax: +212 963-3489
Email: publications@un.org • Web site: http://www.un.org

UNITED STATES OF AMERICA
Bernan Associates, 4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4346
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com · Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 812 Proctor Ave., Ogdensburg, NY, 13669
Telephone: +888 551 7470 (toll-free) • Fax: +888 568 8546 (toll-free)
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

Orders and requests for information may also be addressed directly to:

Marketing and Sales Unit, International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 (or 22530) • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: http://www.iaea.org/books

11-16181

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–113010–5
ISSN 1995–7807