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NUCLEAR ENERGY AGENCY
RADIOACTIVE WASTE MANAGEMENT COMMITTEE

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Working Party on Decommissioning and Dismantling (WPDD)

DECOMMISSIONING FUNDING
ETHICS, IMPLEMENTATION, UNCERTAINTIES

A Status Report

This status report is based on and reflects the viewpoints and materials from several NEA initiatives in connection with decommissioining of nuclear power facilities and with long-term nuclear liabilities management in general. The report also reflects the sharing of experience within the RWMC and WPDD, which represent operators, regulators R&D and policy specialists from countries with advanced nuclear infrastructure that have considerable experience in the field of decommissioning.

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FOREWORD

The Working Party on Decommissioning and Dismantling (WPDD) brings together senior representatives of national organisations who have a broad overview of decommissioning and dismantling (D&D) issues through their work as regulators, implementers, R&D experts or policy makers. The WPDD keeps under review the policy, strategic and regulatory aspects of decommissioning of phased-out nuclear installations in view of the ultimate goal of releasing facilities and sites from regulatory control. The intention is to examine commonalities and differences amongst national programmes, to appraise the state-of-the-art in this field, and to help identify solutions to shared issues.

Status reports of the WPDD are intended to summarise the existing knowledge and experience on a given subject in order to provide concise and "digested" information to those who are interested in obtaining a quick overview over a subject without reading through an extensive number of specialized papers from conferences, seminars or other type of meetings. Status reports are not only addressed to decommissioning experts, e.g. regulators, implementers and R&D experts, but also to any interested audience, including politicians, decision makers and the general public.

A characteristic feature of policies and strategies for the decommissioning of nuclear power facilities are the relatively *long time horizons* involved. Thus, today's generations have to make – and are already making – decisions with consequences reaching out to future generations. In order to be sustainable, these decisions have to be based on ethical considerations, and be possible to implement and take into account a wide range of uncertainties.

The report offers, in a concise form and for non-specialists, an overview of relevant considerations on decommissioning funding with regard to ethics, implementation and uncertainties. The document draws upon a review of recent literature that includes, in particular, information presented and discussed at the following four NEA meetings:

- A Topical session on "Liabilities identification and long-term management at national level", held during the 36th meeting of the RWMC in Paris, March 13, 2003.
- The NEA International Seminar "Strategy Selection for the Decommissioning of Nuclear Facilities, Tarragona (Spain), September 1-4, 2003.
- The NEA International Workshop "Safe, Efficient, and Cost-Effective Decommissioning", Rome, September 6-10, 2004.
- A Topical session on funding issues in connection with decommissioning of nuclear power facilities, arranged by the WPDD in Paris, November 9, 2004.

The main contributions of this report are its overview of ethical principles that are generally applicable to decommissioning and the attending formulation of ethical principles specific to decommissioning funding. The NEA Radioactive Waste Management Committee has participated in the development of this report and endorses its contents.

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1. SUMMARY OF KEY POINTS

A characteristic feature of policies and strategies for the decommissioning of nuclear power facilities are the relatively *long time horizons* involved. Thus, today's generations have to make – and are already making – decisions with consequences reaching out to future generations. In order to be sustainable, these decisions have to be based on ethical considerations, and be possible to implement and take into account a wide range of uncertainties. The purpose of this report is to offer, in a concise form and for non-specialists, an overview of relevant considerations on decommissioning funding with regard to ethics, implementation and uncertainties. Key points are as follows.

Underlying Ethical Principles

- Safety of current and future generations is the paramount concern of decommissioning and decommissioning funding.
- Funding the costs for decommissioning of nuclear power facilities should be guided by the principle of avoiding imposition of undue burdens on future generations.
- The generations using nuclear power facilities have an obligation to assemble and to preserve the financial, technical and scientific resources necessary for the later decommissioning of these facilities. The generally acknowledged 'Polluter Pays Principle', sometimes referred to as "User Pays Principle", should be applied when funding the costs for decommissioning nuclear power facilities.
- A principle of intergenerational continuity (a *chain of responsibilities* whereby the present generation must transfer resources and reasonable obligations to the succeeding generation*)* should also apply.

NEA countries are signatories to a number of international instruments which are based on these recognized ethical principles, most important instrument being the International Joint Convention of the Safety of Spent Nuclear Fuel Management and on the Safety of Radioactive Waste Management.

Implementation

- *Strategies for decommissioning* have a substantial influence on the costs for such operations. Consequently, the choice of decommissioning strategy might also influence the choice of funding method.
- *Decommissioning liabilities* are to be identified and properly managed. This is a prerequisite for all cost calculations.
- *Decommissioning cost calculations* need to be carried out already at the planning stage of a nuclear power facility. They need to be confirmed, updated or supplemented during operation (in order to guarantee sufficient funding) and when the facility is shut down.
- *Decommissioning cost estimates* are made on an iterative, site-specific basis and are a prerequisite for adequate funding. Sufficient margins to account for uncertainties are usually included.
- A *legal and/or regulatory framework* is required for creation of decommissioning funds and for ensuring that funds will not be diverted for other purposes.

- A *funding methodology* is vital. Three main types of funding models are identified, namely direct funding from government, internal segregated or non-segregated funds, and external segregated funds.
- The *precision of the decommissioning cost calculations* is one of the most important prerequisites for establishing adequate funds
- *Estimating the contributions to be paid* is a crucial step.
- *Competent administration of the funding system* is of paramount importance.
- *Economic stability* is necessary for a sound long-term funding system.

Uncertainties

- *Managing of funds over long timescales.*
  Capital that is managed so as to provide a positive return is exposed to different financial risks such as inflation risk, market risks, credit risks, liquidity risks, currency risk and administrative risks. These types of financial risks are the same for all kinds of capital management. The uncertainties that underlie these risks increase with time, which speaks in favour of rigorous management systems, incorporating internal and external review mechanisms, and of not prolonging unduly the start of decommissioning projects.
- *Estimates of decommissioning costs.*
  Minimizing uncertainties of this kind involves continuous development of cost estimates, using the lessons learnt from other decommissioning projects that have been successful or less successful.
- *Early shutdown*
  An early shutdown means that financial resources for decommissioning have to be covered by other sources. A way to insure against such eventualities is to plan for an alternative financing system at an early stage.
- *Time when funds should be available*

  Assets have to be available when required for their purpose. Uncertainty on the timing of major liquidity needs will inevitably result in less well-informed investment decisions.

Overall it can be concluded that:

- Availability of funds at the right time is one of the cornerstones in a successful funding system. Identification of related uncertainties, and implementation of measures to minimise them, are essential for ensuring the availability.
- The accuracy of decommissioning cost calculations is one of the most important prerequisites for establishing adequate funds.
- In most of the NEA member countries, mechanisms for providing decommissioning funding are in place based on Acts of Parliament, Decrees, or Directives, but they differ according to different national legislations and practices.
- Existing systems and practices for funding decommissioning of nuclear power facilities incorporate the “polluter pays principle” with the aim to preserve safety and not to impose undue burdens on future generations.

Finally, it is observed that while this document is focussed on the decommissioning of nuclear power reactors for commercial use, the main findings of the study are also relevant to research reactors and their operators, specifically the underlying ethical principles and the reliability and uncertainties in estimating decommissioning costs.

2. INTRODUCTION

The purpose of decommissioning is to remove some or all of the regulatory controls that apply to a nuclear site, whilst securing the long-term safety of the public and the environment and continuing to protect the health and safety of decommissioning workers in the process. Underlying this are practical objectives including the release of valuable assets such as the site and buildings for unrestricted alternative use, recycling and re-use of materials and the restoration of environmental amenity. Management of spent nuclear fuel is not considered to be part of decommissioning as spent fuel is assumed to have been removed from the facility before actual decommissioning and dismantling work may start..

The average age of nuclear power plants (NPPs) in the OECD/NEA member countries is now about 18 years. The expected *average* operating life span is 30 – 50 years. It follows that the rate of withdrawal from operation will peak somewhere after 2015. In some OECD/NEA countries a number of commercial nuclear power plants have already been shut down for different reasons. In some of these cases decommissioning, including dismantling, has been completed or is in progress. In other cases strategic, conceptual and/or detailed planning for such activities is currently taking place.

Decommissioning of nuclear power facilities might well start 50-60 years after a facility became operational, and a century or more could elapse between the construction of such a facility and the completion of decommissioning. This time horizon is more typical of public infrastructure projects than of commercial industrial projects. These long time frames have important consequences for economic and political decision-making in order to implement principles of sustainable development, including providing the correct regulatory framework and administrative capacity.

Decommissioning issues of common interest are the main emphasis of the Working Party on Decommissioning and Dismantling (WPDD) set up by the NEA Radioactive Waste Management Committee (RWMC) and the Committee on Radiation Protection and Health (CRPPH). Scientific and technical information exchange on decommissioning projects is also carried out within the NEA Co-operative Programme on the Decommissioning of Nuclear Installations (CPD). A Topical session on "Liabilities identification and long term management at national level" was helt during the 36th meeting off the RWMC in Paris on March 13, 2003. An International Seminar "Strategy Selection for the Decommissioning of Nuclear Facilities" was arranged by NEA in Tarragona (Spain) September 1-4, 2003. At the NEA International Workshop "Safe, Efficient and Cost-Effective Decommissioning", Rome, September 6-10, 2004, one session was devoted to "Funding and Costs". A Topical Session on funding issues concerned with decommissioning of nuclear power facilities was arranged by the WPDD in Paris on November 9, 2004.

At the Topical Session November, 2004, a Task Group was set up to prepare this status report focusing on some important aspects in decommissioning funding. The report is structured around the following three areas:

- Underlying ethical principles.
- Implementation of funding.
- Uncertainties in funding.

Generally applicable *Underlying Ethical Principles* to decommissioning funding are reviewed in Chapter 3. This chapter also attempts to formulate ethical principles specific to decommissioning funding. It should be noted that in this document the term "principles" is used in a general sense and

should not be interpreted in a normative way as in e.g. IAEA regulations, guidelines and recommendations.

Chapter 4, *Implementation of Funding,* covers the subjects of inventory of decommissioning liabilities, strategies for decommissioning, estimation of the costs on which to base decommissioning funds, legal requirements for decommissioning funds and funding mechanisms.

Chapter 5, *Uncertainties in Funding,* identifies some of the major uncertainties associated with the accumulation and management of funds and indicates how to minimize them.

3. UNDERLYING ETHICAL PRINCIPLES

Safety of current and future generations is the paramount concern of decommissioning and decommissioning funding.

Current practices in decommissioning are based on an array of technical and societal considerations. A characteristic feature of policies and strategies for the decommissioning of nuclear power facilities are the relatively *long time horizons* involved. Thus, today's generations have to make – and are already making – decisions with consequences reaching out to future generations. In order to be sustainable, these decisions have to be based on ethical considerations, and be possible to implement and take into account a wide range of uncertainties. In particular, ethical principles have been formulated as part of considerations for dealing with the obligations of current and future generations both in international instruments and in national advisory documents. A review of ethical considerations available the literature – in Section 3.1– allows to identify principles – in Section 3.2 – that are specifically relevant to the issue of funding.

3. 1 Ethical considerations

3.1.1 Principles expressed in international instruments

In 1987 the United Nations Commission on Environment and Development (the Bruntland Commission) drew attention to the fact that economic development often leads to deterioration, not an improvement, in the quality of peoples' lives. The Bruntland Commission therefore called for *a form of sustainable development* that meets the needs of the present without compromising the ability of future generations to meet their own needs

The 1992 *Rio Declaration on Environment and Development* forms the basis and the inspiration for much of the recent considerations on environmental issues and sustainable development on a global level. Principle 16 of the declaration states that "National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment".

In 1995, the international Atomic Energy Agency (IAEA) published a document in which fundamental principles of radioactive waste management were formulated (*Safety Fundamentals, IAEA Safety Series No. 111-F) (SF)*. This document constituted a basis for the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.* The following two principles are formulated in the *SF* and have also been reflected in the *Joint Convention*:

- *Avoidance of the imposition of undue burdens on future generations (Principle 5).*
- *Availability of adequate financial resources to ensure the safety of decommissioning of a nuclear facility (Principle 5 paragraph 318, Principle 6 paragraph 323).*

The *Joint Convention* contains a formulation concerning the funding of decommissioning activities that can be interpreted as implying an ethical foundation. This formulation appears both under Chapter 3, Safety of Radioactive Waste Management, Article 11 vii. and under Chapter 2, Safety of Spent Fuel Management, Article 4 vii. According to these articles each Contracting Party shall take the

appropriate steps to "aim to avoid imposing undue burdens on future generations". The concept of "undue burdens" should be interpreted to include any type of burdens, including financial burdens. The Convention leaves it on the Contracting Parties to decide how to achieve this.

Chapter 4 of the *Joint Convention,* concerning General Safety Provisions, Article 26 requires that each Contracting Party shall take the appropriate steps to ensure the safety of decommissioning of a nuclear facility (cf. Principle 9 in the *SF*). Such steps shall ensure that, (i) qualified staff and adequate financial resources are available. Article 22 deals with provision of human and financial resources required for general safety. This article states that each Contracting Party shall take the appropriate steps to ensure that (ii) adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning, and (iii) financial provision is made that will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility (cf. Principle 5 paragraph 318 and Principle 6 paragraph 323 in the *SF*).

At least three other international instruments relevant to activities such as the dismantling or decommissioning of nuclear power facilities touch upon ethical considerations. These instruments are the UN Economic Commission for Europe *Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters* ('Aarhus Convention Agreement'), the *Convention on Environmental Impact Assessment in a Transboundary Context* ('Espoo EIA Convention') and the *Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context* (the 'SEA Protocol'). In none of these, however, the provisions are specific to issues such as costs or funding.

There are also a number of EU-directives containing general ethical considerations to be observed in connection with decommissioning activities, see the reference list. None of these directives, however, contain references to costs or funding of such activities:

Individual countries have dealt with the matter of funding of decommissioning activities by way of their own national legislation and regulations but based on the *SF* and the *Joint Convention*. A multitude of approaches to funding have developed (see Section 4.6).

3.1.2 Principles for making decisions with intergenerational implications

Planning and implementation of large-scale, long-term infrastructure projects always include ethical and moral considerations. A relevant attempt to structure these ethical and moral values has been carried out by a panel of the US National Academy of Public Administration (NAPA), who published a report entitled "Deciding for the Future: Balancing Risks, Costs, and Benefits Fairly Across Generations", in June 1997. In that report four principles for allocation of resources to projects that affect current and future generations (intergenerational decision making) were formulated. The report stated that the four principles *should not be considered alone or in any particular order of importance; they must be considered as a dependent set, with their relationships and relative importance to each other determined from problem-specific contexts*. The principles are formulated as follows:

- *Trustee Principle* – Every generation has obligations as trustee to protect the interests of future generations. The principle describes the present generation's ethical and moral relationship to future generations.
- *Sustainability Principle* – No generation should deprive future generations of the opportunity for a quality of life comparable to its own.

- *Chain of Obligation Principle* - Each generation's primary obligation is to provide for the needs of the living and succeeding generations. Near-term concrete hazards have priority over long-term hypothetical hazards. This principle rests on the philosophical concept of a chain of obligation between generations, whereby one generation passes on to the next the resources and skills necessary for a good quality of life.
- *Precautionary Principle* – Actions that pose a realistic threat of irreversible harm or catastrophic consequences should not be pursued unless there is some compelling countervailing need to benefit either future or current generations.

3.1.3 Principles regarding long-term radioactive waste management projects

Ethical considerations with respect to radioactive waste management have been carried out at the international level since decades. As mentioned in Section 3.1.2, an important result from these discussions is the IAEA document *The Principles of Radioactive Waste Management*, Safety Series No. 111-F, published in the series of *Safety Fundamentals* in 1995.

Ethical discussions have also been carried out in many NEA member countries.

One recent example comes from Sweden. In 2004, a report by KASAM (the National Council for Nuclear Waste, an Advisory Body to Government) developed lines of thought specific to disposal of spent nuclear fuel and focusing on the responsibility of current generations *vis-à-vis* the forthcoming ones.

According to the principle of intergenerational equity, it can be argued that the present generation certainly has an obligation to protect future generations. But how far in the future does such an obligation last and does it always carry with it the same level of responsibility? The KASAM report supports the following three general principles of justice as a basis for the discussion:

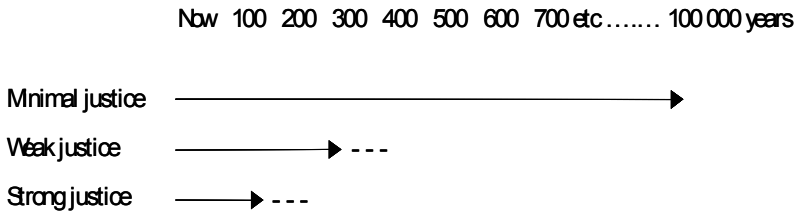
- The *strong* principle of justice

  The present generation has an obligation to exploit or consume natural resources in such a way that subsequent generations can be expected to achieve an equivalent quality of life as the present generation.
- The *weak* principle of justice.

  The present generation has a moral obligation to exploit natural resources in such a manner that not only this generation but also future generations can satisfy their basic needs.
- The *minimal* principle of justice.

  Intrusion into the natural order is a human right. However, the present generation has a moral obligation to exploit or consume natural resources in such a way that we do not jeopardise future generations' possibilities for life.

The three principles of justice are used to illustrate a concept *of diminishing moral responsibility* in time. The main thesis is that we have more extensive obligations towards the generations in our immediate future – and should apply the strong principle of justice towards them (see figure below).



Note: The dashed lines indicate that there are no sharp cut-off points.

The KASAM report suggests that the strong principle of justice is applicable up to some 150 years and may extend up to 300 years. Decommissioning projects belong firmly to the period when the strong principle of justice would apply.

Another example of ethical considerations originates from Switzerland. An expert group (Expertengruppe Entsorgungskonzepte für radioaktive Abfälle, EKRA**)**, set up by the Federal Department for the Environment, Transport, Energy and Communication published a report in 2000 on "Disposal Concepts for Radioactive Waste". As part of its mandate, EKRA investigated scientific and technical aspects of safe waste disposal - taking into consideration the requirement for sustainable development - as well as socio-political aspects. A specific concept for waste disposal was identified and is now codified in the Swiss law [KEG, 2005]. A set of values and objectives was considered and ranked in order of significance in choosing amongst alternatives and reaching the final recommendation. These are:

1. Safety of man and the environment (top priority)

   Safety is necessary for an individual to be able to act, take decisions and make use of his/her freedom. Safety during the whole lifetime of the waste is paramount and should be addressed from today. Assuring safety should constitute as small a burden as possible on future generations.

2. Fairness

   There must be intra- and inter-generational equivalence of opportunities and protection. However, the timescales for radioactive waste management are so long that they exceed the possibilities of our society in terms of passing-on know-how and in terms of stability of political and social institutions. When considering management concepts, a distinction has to be drawn amongst time periods, namely the period that is within grasp of current society and the period during which safety cannot be assured through human presence or intervention.

3. Observing the producer pays principle

   This can be ensured by: (a) securing the financial means for disposal today, independent of the fluctuating economic climate; (b) rapid construction of the facility

4. Individual and social acceptance

   At the time of construction and operation, the facility must be acceptable by the majority of the people, especially those in the siting zone. The facility should be designed in a way that it may be acceptable also to future generations. Individual and social acceptance plays a secondary role because by favouring, within decision making, the present or the immediate

following generations, it infringes to some extent the principle of fairness across generations.[1]

3.1.4 Principles regarding decommissioning projects

At the seminar *Strategy Selection for the Decommissioning of Nuclear Facilities, Tarragona, Spain, 1-4 September 2003*, it was suggested that the following three "Pillars of Trust" should play an overarching role:

- *Safety* – The provisions for safety are closely linked to the availability of the necessary funds as and when required.
- *Participation* – Stakeholder involvement includes early discussion of plans and a continued dialogue with local communities.
- *Economic Development*. – The need for alternative economic activity, future use of the site and compensatory benefits for the community.

There is a certain convergence amongst these principles and those identified earlier. Namely that assurance of safety is essential for communities in the locality of a nuclear facility. This applies to all phases of the plant's life, including decommissioning. Local participation with involvement from politicians or community leaders and the co-operation with local committees are vital.

The presentations at the seminar suggested further that full consideration of concerns about the effects on society such as employment, alternative economic activities, future use of the site and compensatory benefits for the community is important for a successful implementation of decommissioning.

3.2 Formulation of ethical principles regarding decommissioning funding

Internationally acknowledged ethical principles as found in the literature have been presented in the previous section. Decommissioning practice does adhere to those principles. It is worthwhile however to clarify how those principles apply to decommissioning funding.

- *Safety of current and future generations is the paramount concern of decommissioning and decommissioning funding.*

  Safety is necessary for an individual to be able to act, take decisions and make use of his/her freedom. Safety is the first pillar of trust when discussing principles regarding decommissioning projects.

- *The generations using nuclear power facilities have an obligation to assemble and to preserve the financial, technical and scientific resources necessary for the later decommissioning of these facilities.*

1. Indeed, it is accepted that balancing fairly the risks, costs, and benefits across generations requires keeping to principles that are, to some extent, competing with one another, as indicated in Section 3.1.2.

When planning for decommissioning, there are some moral obligations to be considered. One with clearly financial implications is the obligation to preserve resources necessary for future decommissioning activities.

There are other moral obligations that also carry financial implications. One example is that the implementers and the responsible authorities in charge during decommissioning operations have an obligation to protect dismantling personnel, the general public and the environment from excessive risks and, particularly, harmful levels of radiation. Another example is that the generations implementing decommissioning programmes have a responsibility to plan and to carry out such programmes in such a way that the human health of future generations is protected (cf. *SF* Principle 1 and 4).

- *The 'Polluter Pays Principle' should be applied when funding costs for decommissioning nuclear power facilities.*

  The Polluter Pays Principle is generally defined as the principle stating that those causing pollution should meet the clean-up and other costs to which it gives rise. This principle was formulated in 1974, in a recommendation adopted by the OECD Council. The latter re-iterated, in 1989, the applicability of this principle to the management of hazardous facilities. The meaning of the principle was articulated to be as follows: "The Polluter-Pays Principle... means that the polluter should bear the expenses of carrying out the pollution prevention and control measures introduced by public authorities in Member countries, to ensure that the environment is in an acceptable state." The "Polluter Pays" principle was widely adopted internationally in 1992 as part of the Rio Declaration on Environment and Development (Principle 16).

- *Funding costs for decommissioning of nuclear power facilities should be guided by the principle of avoiding imposition of undue burdens on future generations.*

  Avoidance of the imposition of undue burdens on future generations is a key consideration expressed in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and in other internationally and nationally binding provisions (cf. Section 3.1.4 above).

- *When formulating principles for funding and sharing the costs of decommissioning, concepts such as equity and justice are indispensable.*

  Even if concepts such as equity and justice are indispensable, they need to be qualified and defined in more depth before being used in the formulation of ethically sound principles.

  It is easy to argue – in general terms – for a *principle of general equity and justice,* meaning that all humans be treated equally. As decommissioning programmes are long-term activities that involve more than one generation, a *principle of intergenerational equity and justice* can be applied.

- *A principle of intergenerational continuity should apply when formulating principles for funding and sharing the costs of decommissioning across generations.*

  It is argued that the present generation, as well as each succeeding generation, should strive to fulfil the following general goals:

  – Preserve the advances our culture and civilisation has made.
  – Strengthen equitable institutions and the institutions that provide justice.

– Transfer scientific, technological and economic advances to our children and grandchildren.

The principle of intergenerational continuity implies a *chain of responsibilities* whereby the present generation transfers resources and reasonable obligations to the succeeding generation. Each and every generation is considered to have such an obligation. This principle puts obvious constraints on national programmes for decommissioning of nuclear power facilities. The institutions responsible for the decommissioning and decommissioning funding need to be secured. Knowledge, competence and resources need to be preserved, developed and effectively transferred to the next generation.

A key element when applying the principle of intergenerational continuity is the creation and preservation of a system for funding decommissioning when needed. The collection and administration of funds for decommissioning include stringent criteria of financial ethics, such as:

– Preservation and, possibly, increase of financial resources.
– Robustness (that the funds are not sensitive to changes in societal, political and economic scenarios).
– Transparency (with regard to current and future stakeholders).
– Availability when needed.

4. IMPLEMENTATION OF FUNDING

The purpose of this chapter is to discuss various aspects of accumulating and managing funds for decommissioning nuclear power facilities. It should be noted in this regard that the State has the ultimate responsibility, if adequate funds are not available when needed (cf. *Joint Convention* Preamble vi.). From this point of view, the responsible State bodies have a high interest in ensuring the availability of decommissioning funds and minimizing the financial risk to the national budget. It is also up to the State to draft the national legal framework in accordance with the risk that the State is willing to accept or to draft it in such a way that risks to the national budget are minimized.

The NEA Topical Session on "Liabilities identification and long-term management at national level", held 13 March 2003 identified four key issues as a basis for long-term liabilities management:

- A responsible implementing body
- An inventory of liabilities.
- Definitions of management strategies.
- Cost estimations.

In this chapter, these four key issues are dealt with and amplified with more issues specific to funding.

4.1 Decommissioning liabilities – responsible entity

The term 'liability' denotes any legal obligation of an entity. In the current context, *liabilities identification* concerns all the facts that would enable governments, or others to determine whether operators or owners of nuclear installations have provided, or are providing, the requisite financial resources in time to cover the future costs of decommissioning, remediation, and waste management. *Liabilities management* is the set of arrangements designed to ensure that appropriate systems are in place for accrual of funds, for their management, and for their disbursement at the appropriate time.

There is a need for a responsible implementing body to discharge the liabilities.

4.2 Inventory of decommissioning liabilities

Preparation of an *inventory of decommissioning liabilities* consists of locating and recording the installations and sites where radioactive materials are present, and evaluating the situation in order to develop a policy that offers the requisite financial guarantees for safety in the long term. This involves the following specific actions:

- Establishing an information base of the location and the state of all nuclear installations and all sites (including historical sites) that contain radioactive materials.
- Estimating the costs of dismantling, site remediation and managing the resulting materials and waste.
- Evaluating the existence and adequacy (i.e. sufficiency and availability) of the provisions for financing these current and future operations.
- Updating the information base on a regular basis.

4.3 Strategies for decommissioning

The overall costs of decommissioning are dependent not only upon technical matters such as the type, size and condition of the relevant facility but also upon political and strategic decisions about the timing and end-state. They are also dependent upon national policies and standards for release of materials and sites from regulatory control as this has a direct influence on the amount of radioactive waste for disposal. In addition, labour costs, the costs of waste disposal and financial accounting protocols vary from country to country.

Thus the choice of a decommissioning strategy may have a decisive influence on the costs of decommissioning. It could also influence the choice of funding mechanism.

The basic strategic options for decommissioning of a NPP are:

- Immediate or early dismantling.
- Deferred dismantling.
- Entombment.

Immediate dismantling after removal of the spent fuel and operational waste, is the increasingly preferred strategy for decommissioning. This choice is influenced by the availability of know-how and experienced staff from the operational phase, early reduction of residual risk, the improved security of funding, and the absence of imposition of an undue burden on future generations. This strategy choice may result in cost calculations with a reasonable degree of uncertainty, since predictions and assumptions will only refer to a relatively limited time period.

Deferred dismantling involves postponing the dismantling by several decades. Reasons for choosing such a strategy might be insufficient facilities for disposal of radioactive waste, possible overall benefits from radioactive decay and/or a need for a longer time period for collection of adequate funds. Deferred dismantling is associated with additional costs for providing long-term surveillance and maintenance. Postponing also creates a risk of loss of funds or insufficient fund performance. The decommissioning costs may rise faster than the fund growth.

Entombment is a strategy for encapsulating the facility on site and keeping it isolated until the radionuclides have decayed to levels that allow the site to be released from nuclear regulatory control. This strategy is a kind of near surface disposal, and is currently not a preferred option for commercial nuclear facilities.

Some factors that influence costs are the following:

- Project planning (e.g. Inside-out, or outside-in dismantling).
- Material flows.
- Regulatory / policy requirements, e.g. release criteria for radioactive materials.
- Socio-economic issues.
- Waste management provisions (e.g. recycling vs. direct disposal).
- The availability of a waste management system.
- Staff availability, knowledge management, and organizational issues.
- Site disposition and use after decommissioning.

Since costs and funding arrangements are factors in strategy selection, the process clearly involves an element of feedback and reiteration.

Decommissioning cost calculations need already to be carried out at the planning stage of a facility. They need to be confirmed, updated or supplemented, when the plant is shut down, including an initial plant characterization, which is crucial for the detailed planning process. In this context, knowledge of the facilities available for waste processing, storage and/or disposal is an equally important pre-condition for assessing the decommissioning costs. Good planning, including the knowledge of all the material and waste streams to be generated, is an indispensable prerequisite for a good decommissioning cost calculation.

In terms of decommissioning costs it is also important to balance the costs of disposing radioactive waste versus the release of materials from nuclear regulatory control. Such release includes a process of detailed characterization and/or decontamination of large amounts of low-level radioactive materials. Regulatory clearance levels for the release of materials or waste and of sites may have a major influence on costs.

A conclusion of the discussion in this section is, that the presence and implementation of an appropriate and stable regulatory framework is a clear prerequisite for the decommissioning and dismantling planning and the associated cost calculations.

4.4 Estimation of decommissioning costs

A reference list of the elements for estimating decommissioning cost has been published in a joint EC/IAEA/OECD-NEA document (*Proposed Standardized List of Items for Costing purposes in the Decommissioning of Nuclear Installations*, OECD, 1999). Major elements in this list include:

- Pre-Decommissioning Actions.
- Facility Shutdown Activities.
- Procurement of general Equipment and Material.
- Dismantling Activities.
- Waste Processing, Packaging, Transportation, Storage, and Disposal.
- Site Security, Surveillance, and Maintenance.
- Site Restoration, Cleanup, and Landscaping (green field, site reuse for other industrial or nuclear purposes).
- Project Management, Engineering, and Site Support.
- Social measures.
- Research and Development.
- Fuel and Nuclear Material Management (temporary, or interim, storage of spent fuel).

Decommissioning funds may or may not be called to cover all those cost items. In some national schemes there exist separate funds covering spent fuel management and waste disposal costs. It is essential that each funding scheme is clear on the cost items it covers.

A very important point is that reliability of decommissioning cost estimates needs a good, prior characterization of the plant in question as well as a firm basis on a clear decommissioning planning scheme, including a decision on a decommissioning strategy. They will normally require estimates on a site-specific basis, although this requirement is mitigated in the case of standardized plants.

In addition to choice of decommissioning strategy and the nature of regulatory arrangements, as mentioned previously, the type and size of reactor(s), the number of units on a site, and the operating history of the plant could have a large influence on decommissioning costs. Experience shows, however, that one of the most significant cost elements is management of the low level materials that arise from dismantling and need, either to be disposed of as radioactive waste in a repository, or

re-cycled and re-used. Disposal facilities will be needed for all types of radioactive waste from dismantling. In most cases such facilities are not yet constructed. Thus cost calculations regarding disposal may be uncertain.

Generally, the cost estimate for a project will consist of a base cost, a set of assumptions and some provision for project risks. The accuracy of the estimate will depend not only on the careful assessment of the base costs, but also on a good understanding of the assumptions used in deriving those base costs. It will also depend upon comprehensively identifying the risks to a project and quantifying the consequences of those risks both in terms of cost and duration of the project. Identification and quantification of the project risks will also be necessary in order to choose the optimum contract strategy, which in turn will affect the cost estimate for the project.

Estimates of decommissioning costs have been performed and published by many organizations for many different applications. The results often vary because of differences in methodology and the scope work, and many vary, unavoidably, because the costs of decommissioning are likely to be case specific at the level of detail necessary for high accuracy and reliability (cf. UNIPEDE/EURELECTRIC *Cost Estimates for Decommissioning Nuclear Reactors Why do they differ so much?* 1998).

In a recent IAEA publication, *Financial Aspects of Decommissioning, IAEA-TECDOC-1476*, three main types of cost estimates have been identified from a methodological point of view and with different levels of accuracy. These types of estimates can be summarized as follows:

- *Order-of-magnitude estimate*. Used when having a project without detailed engineering data, where an estimate is prepared using scaling factors. It is likely that the overall scope of the project has not been well defined. The level of accuracy expected is -30 % to + 50 %.
- *Budgetary estimate*. Estimation based on the use of flow sheets, layout and equipment details, where the scope of the project has been defined, but not in detail. The level of accuracy expected is -15 % to +30 %.
- *Definitive estimate*. Used where the details of the project have been prepared and its scope and depth are well defined. The level of accuracy expected is -5 % to + 15 %.

Clearly, cost estimators are required to exercise judgment as to the level of accuracy that the input data will support. Sufficient margins to accommodate the associated uncertainties are then identified.

Increasingly sophisticated cost estimation methodologies have been developed over the last 20 years or so. Some of the more common estimating techniques are as follows (cf. *IAEA-TECDOC-1476):*

- *Bottom-up technique*. Generally, a work statement and set of drawings or specifications are used to identify material quantities associated with each discrete task to be performed in accomplishing a given activity. From these quantities, direct labour, equipment and overhead costs can be derived.
- *Specific analogue technique*. Specific analogues depend upon the known cost of an activity or item used in prior estimates as the basis, in a new estimate, for the cost of a similar activity or item.
- *Parametric technique*. Parametric estimating is based on historical cost databases for similar systems or subsystems.
- *Cost review and update technique*. An estimate may be constructed by examining previous estimates of the same or similar projects for internal logic, completeness of scope, assumptions and estimating methodology.

- *Bidding technique.* An estimate is based on the results from a bidding procedure regarding the actual planned decommissioning work.
- *Expert opinion technique*. This may be used when other techniques or data are not available.

The owners of nuclear facilities may need to prepare decommissioning cost calculations for regulatory review. In each case the costs are site-specific. Generalizations or approximations drawn from other facilities are usually regarded as inappropriate as the basis for establishing funding arrangements.

Irrespective of the methodology used it is important that cost estimates are periodically reassessed both during the operation and decommissioning phases.

One recent example of work aimed at improving consistency in decommissioning cost estimates is reported in the OECD/NEA publication *Decommissioning of Nuclear Power Plants – Policies, Strategies and Costs (2003).* A further example of harmonisation work regarding decommissioning cost estimates is the *IAEA-TECDOC-1322 (2002) Decommissioning Costs of WWER-440 Nuclear Power Plants. Interim Report: Data Collection and Preliminary Evaluations.*

4.5 Legal requirements for decommissioning funding

A legal and/or regulatory framework is necessary for ensuring that financial resources are sufficient and available to cover all decommissioning and waste management costs and to prevent any misuse of the funds. Furthermore, it is vital that mechanisms for securing funds are structured and managed to keep pace with inflation and cost escalation. This is to ensure adequacy of funding, as it is unwise und unsafe to start decommissioning without sufficient funds to complete the process.

Thus, the legal basis for creation of the funds is to ensure that they will not be inappropriately diverted for other purposes and, in addition, that they meet the following minimum criteria:

- *Polluter-Pays Principle***:** Contributions to the fund are to be made by nuclear installations during their operation to reach, at the latest by the time of final shutdown, a level that is sufficient to cover all decommissioning and waste management expenses**.**
- *Sufficiency:* In order to cover the costs of decommissioning of the installation and the long-term management of decommissioning radioactive wastes the contributions are to be in line both with the total fund collection period, and the strategy chosen for decommissioning,.
- *Availability:* The funds are to be available at the appropriate time. It is vital to manage and periodically review the funds in a manner that ensures a level of liquidity compatible with the timetable for decommissioning liabilities and their costs**.**
- *Transparency:* The funds are to be used only to cover the costs of the decommissioning obligations in line with the decommissioning strategy, and not be used for other purposes. The funds must be transparent to the respective national authorities and other relevant stakeholders as regards the accumulation of money, the expenses and the financial management. It is also necessary that the funding system complies with national tax laws**.**

The NEA Topical Session on "Liabilities identification and long-term management at national level" observed "that there are Acts of Parliament, Decrees, or Directives, which provide the authority for the funds to be established and preserved". This statement is valid for most NEA member countries. The intention is to ensure that money for decommissioning nuclear installations will be available when needed, and that no unfunded liabilities at the end will have to be covered by the national budget. For

this reason, it is important to review decommissioning cost estimates periodically. These are key elements in designing and implementing a coherent and comprehensive national decommissioning policy, including the legal and regulatory bases for the collection, saving and use of decommissioning funds.

Recently EC has made an effort on harmonization of decommissioning funding. In a communication from the EU Commission to the European Parliament and the Council 26 October, 2004 (COM /2004/719 final) the Commission presented its current conclusions with regard to the matter of use of financial resources earmarked for the decommissioning of nuclear power plants. The communication included an announcement by the Commission stating that it intended to obtain more detailed information from member States giving a clearer picture of such key factors as the way decommissioning costs are calculated, the adequacy of the assembled resources, the guarantee that resources will be available when the time comes, and the way they are managed. A report by the European Commission with the preliminary title "Commission Recommendation on the Management of Financial Resources for the Decommissioning of Nuclear Installations, Spent Fuel and Radioactive Waste" is expected to be published during 2006.

4.6 Funding

4.6.1 Funding arrangements

Financial assets, or 'funds', to cover decommissioning costs, are currently being set aside in most countries with nuclear power programmes. This is a conclusion that can be drawn from studies of funding arrangements in the NEA Member countries[2]. As various mechanisms exist for accumulating and managing these funds to ensure availability at the right time, and as the types of costs to be covered by the funds also vary, the approaches to funding differ from country to country.

Three main types of funding models are identified:

- Funding from government.
- Internal segregated or non-segregated funds.
- External segregated funds.

Funding from Government applies when the Government is the owner of a facility. This is typically the case of research reactors. In such a case the Government may pay its expenses from the annual budget or pay into a fund[3]. Government intervention in providing funding for decommissioning of commercial nuclear power facilities could constitute a threat to fair competition within the energy producing sector, nationally and internationally.

2. Some of the information in section 4.6 is based on a presentation by *F. TCHAPGA*, given at the Topical Session on Funding Issues in Connection with Decommissioning of Nuclear Power Plants (held during the 5th meeting of the WPDD in Paris November 9, 2004). Examples of funding management are provided in the NEA topical session on "Liabilities identification and long-term management at national level"

3. Research reactors – as well as other facilities built for non-commercial use – form a special category in that the role of government for funding is especially predominant. In the main, this document is focussed on the decommissioning of nuclear power reactors for commercial use. The main findings of the study, are also relevant to research reactors and their operators, however, specifically the underlying ethical principles and the reliability and uncertainties in estimating decommissioning costs.

In the "Internal segregated or non-segregated fund model", the funds are managed within operating organisations. Operators are responsible for collection of financial resources. This model is used in nearly 50% of the NEA Member Countries.

In the "External, segregated fund model", the funds are managed externally, by a dedicated independent body which may be a private or state-owned entity. Such funds may be centralised (for the entire industry), or decentralised (with as many funds as there are operators).

Arguments have been raised that fund management by a truly independent body might have advantages over management by operators or even governments, whose priorities for funding may result in the funds being used for other purposes. But even in the case of an independent body, there are hazards, ranging from errors in the assumptions about inflation, the discount rates used for the estimation of the funds required, to a simple loss in value of the assets held by the fund.

4.6.2 Raising of funds

The way in which decommissioning funds are accumulated varies from country to country. In the case of a NPP, funds for decommissioning are set aside from revenue from the sale of electricity generated by the plant during its operational phase or through a levy on sales of electricity of any origin. A levy may also be applied to the net profits that the operator may make from other goods and services it may provide.

Several different approaches to fund collection can be used:

- Collection over a fixed period of time by annual payment up to the expected operational life time.
- Collection as a prepayment to the fund before start-up.
- Collection at the start of decommissioning (not recommended since normally the revenue from electricity production is the basis for the fund).

When estimating a reasonable collection period and the size of the annual contributions to a fund, several important assumptions regarding:

- Varying inflation rates during the collection time of the funds.
- Varying interest rates on the accumulated capital.
- Level of uncertainty of the decommissioning costs.
- When in time the costs will arise.
- Risk of premature shutdown and thereby loss of revenue.

4.6.3 Management and control of funds

The total assets in a decommissioning fund – at a given time – are the result of both the contributions to the fund and its financial management. Thus, conscientious management of funds is important. A balance is required between the greatest possible return on the investment and the conservative approach needed to protect the capital in the fund. Limitations on the type of investments allowed are often set by Governments.

In some countries, the operators are allowed to accumulate and manage their own decommissioning funds, which remain in their own accounts (i.e. internal management of the funds, see Section 4.6.1). The operators have full responsibility for the respective investment and they have to compensate any losses.

In other countries, the funds are collected from the operators or the electricity consumers and managed by separate, independent bodies (i.e. external management, see Section 4.6.1). The organisation responsible for the fund needs to manage and control the assets in such a way as to ensure that the fund at least retain its value and is not disbursed on anything, other than its identified purpose. In the case of external management, compensation for any losses may need to be addressed in the legal and regulatory framework. The framework may also ensure that internal funds are not lost by, for example, bankruptcy of the owner of the facility.

Calculations of future costs are expected to meet high accuracy standards and be subjected to regular and frequent review. Also, it is important that the real value of assets in the fund is safeguarded against periods of high inflation. For all of these reasons, competent administration of the funding system, whether internal or external is of paramount importance.

The management of the accumulated assets of the fund may be entrusted to a variety of custodian banks or asset managers for the purpose of investing them. The options for asset management include investment in national currency bonds, international currency bonds, national equities and international equities or investment in real estate. In any case the protection and security of the funds are of top priority, while recognising the unpredictable nature of investment in the stock market.

All fund management models share a common challenge, namely, the risk of premature decommissioning, financial difficulties in the operating company, or change of ownership of the operating company. In such cases the financial resources necessary for decommissioning might be protected, e.g. by:

- An insurance policy.
- A bank guarantee.
- A joint liability between operators of nuclear power facilities.

5. UNCERTAINTIES IN FUNDING

In the NEA Topical Session on "Liabilities identification and long-term management at national level", held 13 March 2003 in Paris, France it was concluded that there are considerable uncertainties related to the growth of the funds as a result of the chosen investment strategy, the management/mismanagement of the fund, and the inflation rate. These suggest that a balance is required between the rate of return and the preservation of the fund value in order to preserve the fund value for future implementation of waste management and/or disposal programs."

In the following text, uncertainties in decommissioning funding are grouped into four areas:

- Estimation of decommissioning costs
- Consequences of early shutdown
- Time for availability of funds
- Management of funds over long timescales

These areas of uncertainty have a degree of interdependence on one another. Particularly in the case of external funds, the need for inflow of more resources is dependent on how well the accumulated resources are managed, on the accuracy of cost estimations and on the uncertainties associated with prediction of when funds will be needed for decommissioning operations. In regard to management of funds over long time scales, uncertainties regarding the time factor also affect the nature of investment decisions and, thus, the results of fund management.

5.1 Estimation of decommissioning costs

The precision of the decommissioning cost calculations is one of the most important prerequisites for establishing adequate funds. The difficulties in cost calculation have been illustrated in the NEA-report *Decommissioning Nuclear Power Plants – Policies, Strategies and Costs* (2003) and in some of the papers presented at the NEA Workshop in Rome, in September 2004. The issue of cost calculations has also been studied by IAEA. Recent IAEA publications on this issue are *Status of the Decommissioning of Nuclear Facilities around the World,* (2004), and *Financial aspects of Decommissioning* IAEA-TECDOC-1476, (2005).

The above mentioned NEA-report shows that the average decommissioning cost is about US $320 million for a 1000 MWe pressurized water reactor and US $420 million for a 1 000 MWe boiling water reactor.

According to the first IAEA report mentioned above, the decommissioning costs for nuclear power reactors situated in different countries, and for different reactor types, can vary over a wide range, from US $250 million to $500 million, with an assumed median value of $350 million.

Such variations may of course be genuinely dependent on project and country specific factors, rather than due to uncertainties. From the Rome workshop it may be observed *[Ref.]*, however, that even in the most accurate case, a definitive estimate (as defined in Section 3.3) is only accurate to -5% to +15 %. Thus, when developing a funding basis for a project, the estimator must include sufficient margin in the budget to account for this level of uncertainty.

Minimising uncertainties involves continuous development of cost estimates, using the lessons learnt from other decommissioning projects that have been successful or less successful. As mentioned in Section 3.3 it is important that such reassessments of decommissioning costs are done periodically throughout both the operating and decommissioning phases of a nuclear power facility.

5.2 Consequences of early shutdown

Another prerequisite for securing adequate funding is operation of a nuclear power facility for long enough to earn sufficient revenue, through the production of electricity, to cover its future decommissioning costs. An early shutdown usually means, mainly in the cases of external funds, that financial resources for decommissioning have to be covered by other sources. In these cases a way to insure against such eventualities is to plan for an alternative financing system at an early stage.

5.3 Time for availability of funds

One of the duties of a fund manager is to have assets available when needed for their purpose. Careful liquidity planning is essential, and is dependent on reliable forecasts of when major costs will occur. When considering different investment options, it is most important for a capital manager to know whether the invested assets need to be available to meet costs within 5-10 years or 30 years ahead.

Uncertainties in this time factor depend largely on the kind of decommissioning strategy or decommissioning policy that has – or has not – been adopted in a country. Such uncertainties result inevitably in less well-informed investment decisions.

5.4 Management of funds over long timescales

It is vital that funds that are collected for future use are managed to ensure that their real value is maintained. In an inflationary economy this means that management is expected to ensure that the accumulated resources grow at least as fast as the rate of inflation. A more ambitious goal is to ensure that real value is increased before the assets have to be used for their intended purpose.

Capital that is managed so as to provide a positive return is exposed to different financial risks such as inflation risk, market risks, credit risks, liquidity risks, currency risk and administrative risks. These types of financial risks are the same for all kinds of capital management. It is necessary to establish a balance between the expected return on capital invested and the risk to be accepted in order to obtain that return. Generally, seeking a higher return involves accepting a higher level of risk. This balance will generally establish the kind of assets into which the fund capital may be invested. The responsibility to establish risk acceptability limits normally rests with Governments.

Economic stability is also necessary for a sound long-term funding system. Nevertheless, it is possible that a nation might get into such deep economic difficulties that legislation is introduced in order to allow the use of accumulated funds for purposes other than those originally intended. Criminal misuse of funds is also a possibility and can not to be ruled out. Warfare could lead to a total loss of funds as experience from the First and Second World War shows.

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