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Decommissioning costs of WWER-440 nuclear power plants

Interim report: Data collection and preliminary evaluations

INTERNATIONAL ATOMIC ENERGY AGENCY

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FOREWORD

A large number of the existing nuclear power plants (NNPs) started their operation at the 1970s and 1980s. As the typical design lifetime of a nuclear power reactor is 30 to 40 years, many of these reactors will reach the end of their planned operational period in the coming decade.

Utilities operating such reactors have now to consider whether they will replace the NPPs reaching their planned end of life, or refurbish the plants and extend their service life. This very complex problem involves many issues: technical feasibility, economic viability, licensing and public acceptance have to be taken into consideration and carefully analysed. Within this context, the economic assessment of decommissioning plays a significant role, as well.

In a previous IAEA technical publication, Review of Selected Cost Drivers for Decisions on Continued Operation of Older Nuclear Reactors — Safety Upgrades, Lifetime Extension, Decommissioning, a review was given of information that had been published about the cost of the three activities referred to, being part of the cost/benefit analysis relating to the management of the lifetime of a NPP. While each of the activities may be the subject of detailed specialised cost studies, the publication viewed the cost globally. It was found to be useful, and it was indicated that Member States showed interest in the topic.

During compilation of the review of the decommissioning costs, it was found that decommissioning costs for Western type reactors (PWRs, BWRs) had been relatively well studied. Several in-depth international studies were available which provided detailed analyses and explained reasons for differences in decommissioning cost estimates from one country to another. The situation with Soviet-designed reactors (WWERs, RBMKs) appeared to be different. While many valuable national cost studies had been carried out, international comparisons of these studies are rare and reasons for cost differences for the same reactor units are not clearly understood.

Based on these evaluations and considering the interest in decommissioning costs within Member States, especially within WWER-440 operating countries that face the complex decision about continued operation vs. decommissioning in the near future, the IAEA launched the task to prepare a technical document on Decommissioning Costs of WWER-440 Nuclear Power Plants.

The IAEA wishes to thank all the participants and their Member States for their valuable contributions. The IAEA officer responsible for this publication was P. Trampus of the Division of Nuclear Power.

EDITORIAL NOTE

CONTENTS

ANNEXES 1–9: STATUS REPORTS FROM THE PARTICIPATING MEMBER STATES

SUMMARY

Based on the interest in decommissioning costs within Member States, especially in WWER-440 operating countries that face the complex decision about continued operation vs. decommissioning in the near future, the IAEA launched the task to prepare a technical document on "Decommissioning costs of WWER-440 nuclear power plants". The main objectives of this publication were to present the decommissioning costs of WWER-440 NPPs in a uniform manner, i.e. using the cost item and cost group system of the Interim Technical Document on Nuclear Decommissioning "A Proposed Standardised List of Items for Costing Purposes" developed jointly by the EC, the IAEA and the OECD Nuclear Energy Agency (NEA), and providing, as such, a basis for understanding decommissioning costs differences.

Member States operating WWER-440 NPPs or having such units under shutdown or even under decommissioning conditions have been requested to provide cost estimates and other input data in order to facilitate understanding of their cost figures. Both decommissioning options, i.e. immediate decommissioning and safe enclosure, have been considered. In the aforementioned joint Interim Technical Document, cost items related to activities that are carried out with a similar emphasis, whether or not tied to a similar time schedule for decommissioning, or that are based on overall activities that cannot be categorised in a specific time period, are grouped as follows:

01 Pre-decommissioning actions;

02 Facility shutdown activities;

03 Procurement of general equipment and material;

04 Dismantling activities;

05 Waste processing, storage and disposal;

06 Site security, surveillance and maintenance;

07 Site restoration, cleanup and landscaping;

08 Project management, engineering and site support;

09 Research and development;

10 Fuel and nuclear material;

11 Other costs.

Before starting implementation of the study, agreement was obtained on general financial, technical and social boundary conditions that should be used in order to facilitate comparison of data. As a result, the cost figures were collected in a recommended structure and analysed. During progress of work, experts of participating Member States responded to a questionnaire, and explained the contents of individual cost items and cost groups during subsequent discussions. Comparison of cost estimates in the various decommissioning projects showed to be rather difficult, even with the support of the standardised list of items for costing purposes. In each country, the existing cost figures were many times allocated to different cost codes, and it was difficult to re-allocate costs that were grouped based on the individual costing methodologies. Verification of cost figures was sometimes executed while comparing with previous IAEA as well as OECD/NEA studies.

The total costs for the immediate decommissioning option vary from 219 MUSD (Finland) to 1,370 MUSD (Germany). This large difference is mainly due to country and site specific conditions. In the case of Finland the possibility for on-site disposal of all dismantled material

reduces the costs dramatically. In the case of the Greifswald project (Germany) major costs for post-operational and site support activities, as well as the construction of a large interim storage on the site are included. For the safe enclosure option the cost figures vary from 210 MUSD (Czech Republic) to 469 MUSD (Hungary). In this case the spread in the cost estimations is smaller, but still significant, the reason for this being the different scopes that are included. At this stage of cost estimating in the participating countries, overall comparisons seem to be premature and it is necessary to look at the detail of each cost item.

Comparing the cost categories “Labour Costs; Capital, Equipment and Material Costs; and Expenses” has demonstrated that labour represents about 50 % of the total decommissioning costs. Comparing these results with former OECD/NEA cost studies shows quite good agreement. It may be concluded, therefore, that WWER-440 NPPs are certainly not “unique” from the point of view of their decommissioning costs.

The current exercise was the first one in which decommissioning costs were converted to and presented in accordance with the joint Interim Technical Document. It made cost figures comparable and contributed to better understand costs differences as specific characteristics of individual cost items could be identified and clarified. For some cost items, relatively large scattering could be explained by the fact that in some countries certain cost factors are not well known, i.e., in fact no decision has yet been taken. On the other hand, large scattering also resulted from differences in the applied decommissioning strategy, i.e., the scope of decommissioning or the regulatory approach. It might also be the result of some uncertainty in converting the costs from the existing cost structures to the newly recommended one. Nevertheless, the study clearly indicated the benefit of the uniform cost structure.

Estimating decommissioning costs is an ongoing task in any country that operates nuclear installations. Improved and more reliable cost figures may be obtained in future when increased progress is made in decommissioning planning and more experience is gained in the application of the recommended cost structure. The current document should therefore be considered as an interim document. It is recommended, to revisit this interim cost study in about three to five years. In addition, a more detailed description of the items comprised in the cost matrix of the reference document is recommended. It is expected that as a result of these recommendations and due to the periodic updating of cost estimates, future cost figures will become more precise.

1. INTRODUCTION

The preparation of this publication is part of the project entitled Nuclear Power Plant Life Management Including Decommissioning. The project objective is to optimise plant service life, including decommissioning, through the application of technological and engineering best practices including quality assurance and quality management and the utilisation of relevant databases. The preparation of this TECDOC is a continuation of a previous technical document of the IAEA: “Review of selected cost drivers for decision on continued operation of older nuclear reactors – safety upgrades, lifetime extension, decommissioning” [1].

The task is very topical because up to now six out of the 35 WWER-440 nuclear units (water cooled water moderated power reactor) that have been put in operation in the past, have been finally shut down; five of them in Germany and one in Armenia. In addition, following an agreement between the European Commission (EC) and the Bulgarian Government, it was decided that units 1 and 2 of Kozloduy NPP should be permanently shut down before 2003.

Figure 1–1 shows the end of the design lifetime (30 years) of the units currently in operation if their service life will not be extended. In this case, shutdown of the major part of the facilities would be between 2001-2007 and 2010-2017, respectively. Extending the plant service life against the lifetime considered by the designer is, however, an issue in many countries operating WWER-440 NPPs. For some WWER-440/213, extension of the lifetime up to 45 years of operation seems to be a real technical possibility and a viable economic solution as well.

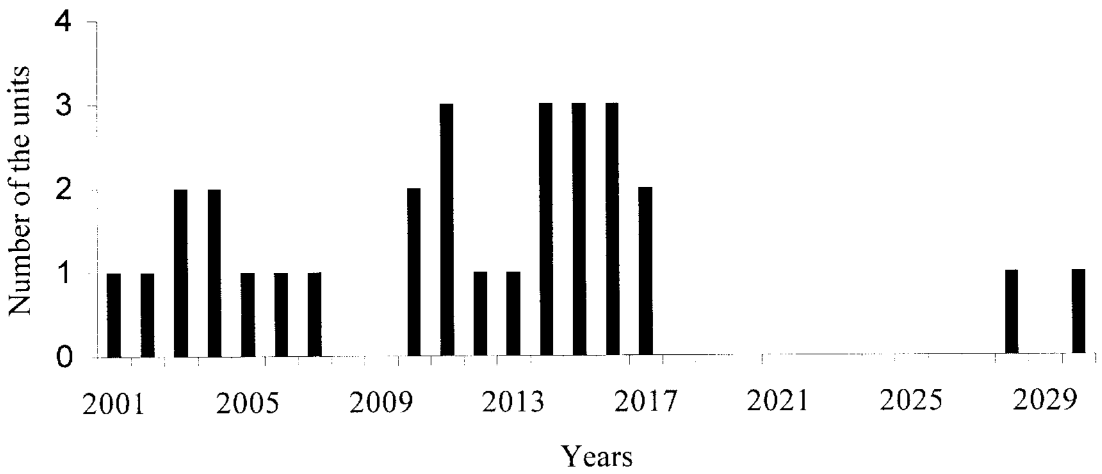

Figure 1-1. Expected end of design lifetime of existing WWER-440 units.

The objectives of this publication are:

(a) To present the decommissioning costs of WWER-440 NPPs in a uniform manner, i.e., using the cost item and cost group system of the Interim Technical Document on Nuclear Decommissioning “A Proposed Standardised List of Items for Costing Purposes”, jointly developed by the EC, the IAEA and the OECD/Nuclear Energy Agency (NEA) [2].

(b) To provide a basis for understanding decommissioning costs differences in case of WWER-440 NPPs.

The presentation of the existing decommissioning cost estimates for WWER-440 reactors is mainly based on expert assessment. A final decommissioning plan was only prepared or initiated in these countries where facilities were finally shutdown or decommissioning activities were actually started.

The study may also be used for more detailed considerations about the methodology of comparing costs (review the considered scope of decommissioning, use of market exchange rates or purchasing parities in cost conversions, approach to handling different regulatory environments, etc.). The document is not aiming to perform any statistical analysis, however.

Organisations that participated in this decommissioning cost study, and reference NPPs are shown in Table 1–1. Since WWER-440 NPPs have usually been built as twin units, the reference NPPs always consider two units.

Table 1-1. Participating organisations and reference NPPs

Country	Organisation, mailing address	Reference NPP	Type of the units
Armenia	Ministry of Energy 2, Government House, Republic Square, 375010 Yerevan, Armenia	Armenian NPP Units 1-2	WWER-440/270
Bulgaria	Ministery of Energy and Energy Resources 8, Triaditza Str., 1040 Sofia, Bulgaria	Kozloduy NPP Units 1-2	WWER-440/230
Czech Republic	Czech Power Company (CEZ) Jungmannova 29-35, 11148 Prague 1, Czech Republic	Dukovany NPP Units 1-2	WWER-440/213
Finland	Fortum Nuclear Services Ltd. P.O.Box 10, 00048 Fortum, Rajatorpantie 8,Vantaa, Finland	Loviisa NPP Units 1-2	WWER-440/213
Germany	Energiewerke Nord GmbH, P.O.Box 1125, 17507 Lubmin, Germany	Greifswald NPP Units 1-2	WWER-440/230
Hungary	Public Agency for Radioactive Waste Management P.O.Box 12, 7031 Paks, Hungary	Paks NPP Units 1-2	WWER-440/213
Russian Federation	VNIIAES (All-Russian Research Institute for NPP Operation) 25 Ferganskaya Str, 109507 Moscow, Russian Federation	Novovoronezh NPP Units 3-4, Kola NPP Units 3-4	WWER-440/230 WWER-440/213
Slovakia	DECOM Slovakia Ltd. Jana Bottu 2, 91701 Trnava, Slovakia	Bohunice NPP Units 1-2 (V-1), Units 3-4 (V-2)	 WWER-440/230 WWER-440/213
Ukraine	State Scientific Engineering Center of Control System and Emergency Response 64/56, G. Stalingrada Str. 254123 Kiev, Ukraine	Rovno NPP Units 1-2	WWER-440/213

Studies that are currently available relating to these reference plants primarily aim at developing a decommissioning strategy and evaluate proposed options. Cost estimations that were carried out in the framework of these studies were accomplished for the following options:

(a) Immediate decommissioning (i.e. immediate dismantling),

(b) Safe enclosure (i.e., deferred decommissioning).

The safe enclosure option has been worked out for the following versions:

(a) Safe enclosure for certain parts of the reactor confinement of each unit separately;

(b) Safe enclosure for the reactor shaft only;

(c) Safe enclosure for the complete reactor building;

(d) Monitored safe enclosure for all contaminated facilities.

As in most of the Member States participating in this study, cost estimates for both immediate decommissioning and safe enclosure were available, the decision was taken to include both options. As studies accomplished in a same country were not simultaneously completed, they might not have the same value or impact. It should also be mentioned that two participating Member States (Finland and Germany) are members of the European Union (EU), and have a highly developed industry as well as an economy with a comparatively high gross domestic product (GDP).

The Interim Technical Document [2] was accomplished in 1999, in practice after completion of the studies that were available for this exercise. As in these studies costs were categorised according to local individual specifications, and it was decided to use the cost item and cost group system recommended in [2] as a reference, the cost figures had to be re-categorised accordingly.

Though this publication is mainly aiming at presenting and analysing decommissioning costs of WWER-440 NPPs - as is indicated in the title - the participants considered that it should also deal with some questions related to the decommissioning process itself that have a decisive effect on the selection of a strategy, e.g., collective dose estimation and time scheduling. As a result, these elements were also included in the study.

Up to now, specific software developed for cost estimation has only been used in Germany. Within a recent EC project on the decommissioning of the Kozloduy NPP units 1-2, detailed cost estimates were performed on the basis of the know-how accumulated in the Greifswald project. Future work for Kozloduy will be supported by software that is further developed and implemented in Bulgaria in the framework of an IAEA Technical Co-operation. With technical assistance of the Department of Energy of the United States, calculations were also made for Armenia for which an adapted software was used. Currently, Slovakia is engaged in a software development that should produce results in accordance to the proposed standardised list [2]. This software is intended to be used for cost estimating for ongoing and future decommissioning projects in the Slovakia and is expected to be ready for use in 2002. In other countries, commercially available software tools are used for implementing cost estimations.

Estimating decommissioning costs is an ongoing task in any country that operates NPPs. Improved and more reliable cost figures may be obtained in future when increased progress is made in decommissioning planning and more experience is gained in the application of the recommended cost structure. The current document should therefore be considered as an interim document. It is recommended to revisit this interim cost study in about three to five years.

2. TECHNICAL DESCRIPTION OF THE WWER-440 REACTORS

2.1. BRIEF HISTORY OF WWER-440S

Design of the WWER in the former Soviet Union was started in 1954-1955 [3]. The first generation of commercially operated 440 MW(e) WWERs (model 230) was constructed based on the experience gathered with the two units of Novovoronezh NPP. From 1971 to 1980 six units of that type were put into operation within the former Soviet Union, at Novovoronezh, Kola, Metsamor (this is the only model 270, see explanation in 2.3.), and Rovno. From 1974 to 1982, ten additional units were put into service outside the former Soviet Union, in Bulgaria, former Czechoslovakia and former German Democratic Republic.

A decisive role in developing new approaches to ensure NPP safety resulted from the design of the WWER-440 NPP for Finland, which was started in 1969. The first units of this new series were erected at the site of the Loviisa NPP in Finland (model 213). From that moment on, in all plans for the construction of NPPs in the former Soviet Union and the former Eastern European countries, the technology of this new series of NPPs was applied, i.e., for four plants in the former Soviet Union and eleven outside, including former Czechoslovakia, former German Democratic Republic, and Hungary. The last two units of the model 213 reactor were constructed and put in operation in the Slovakia.

A list of WWER-440 units both in operation and shutdown is shown in Table 2-1 [4].

All WWER-440 NPPs have six loops, isolation valves on each loop, horizontal steam generators, rack and pinion type control rod drives and generally all 220 MW(e) steam turbines. They use hexagonal fuel assemblies containing 126 fuel rod positions. Electrical power output of the units varies between 408 MW(e) and 510 MW(e) after power upgrade. The actual electrical power output was used to calculate the specific decommissioning costs as indicated in Section 7.

Except for the Loviisa NPP in Finland, the NPPs involved in the study are currently state-owned, or most of their shares are state-owned. The number of employees on site of the NPPs at the time of shutdown is expected to vary between 470 and 5,000. These data refer to the whole plant sites and not to the twin units that are the basis for the comparison.

2.2. TECHNICAL DESCRIPTION OF THE WWER-440 MODEL 230 REACTORS

The WWER-440/230 only relies on local area compartmentalisation to prevent the release of fission products. The design basis accident is a pipe rupture with an effective 100 mm diameter carrying a unidirectional flow reduced by special orifices. The model 230 comprises makeup coolant pumps with a limited capability for emergency core cooling, but has no Emergency Core Cooling System (ECCS) as such. The sealed accident localisation compartments contain a pressure release valve intended to relieve over-pressure and subsequent closure after pressure level normalised. In some cases, the reactor pressure vessel inside surface is cladded. The model uses low inertia canned motor pumps.

Table 2-1. WWER 440 reactor units

Country	NPP	Unit	Model	Start of operation	End of design lifetime*
Armenia	Armenian	1	270	1976	Shutdown in 1989
		2	270	1980	2015**
Bulgaria	Kozloduy	1	230	1974	2004***
		2	230	1975	2005***
		3	230	1980	2010
		4	230	1982	2012
Czech Republic	Dukovany	1	213	1985	2015
		2	213	1986	2016
		3	213	1986	2016
		4	213	1987	2017
Finland	Loviisa	1	213	1977	2007
		2	213	1981	2011
Germany	Greifswald	1	230	1973	Shutdown of all units in 1990
		2	230	1974	
		3	230	1978	
		4	230	1979	
		5	213	1988	
Hungary	Paks	1	213	1983	2013
		2	213	1984	2014
		3	213	1986	2016
		4	213	1987	2017
Russian Federation	Novovoronezh	3	230	1971	2001
		4	230	1972	2002
	Kola	1	230	1973	2003
		2	230	1974	2004
		3	213	1981	2011
		4	213	1984	2014
Slovakia	Bohunice	1	230	1978	2003
		2	230	1981	2006
		3	213	1984	2014
		4	213	1985	2015
	Mochovce	1	213	1998	2028
		2	213	2000	2030
Ukraine	Rovno	1	213	1980	2010
		2	213	1981	2011

* 30 years
** Including 5 years of cold shutdown
*** Final shutdown at the end of 2002

2.3. TECHNICAL DESCRIPTION OF THE WWER-440 MODEL 270 REACTORS

The design of the Armenian NPP (ANPP) was based on the model 230. It was improved considering the specific conditions of the plant location - a seismic hazard of magnitude 8 on the MSK-64 scale. This specific feature of the plant required basic design developments of the model 230, not only referring to its construction but to the facility as a whole, changing the type of reactor to model 270.

The key differences between the model 230 and 270 reactors are:

(a) The model 270 reactor pressure vessel comprises a special pressure vessel support girder and is firmly fastened to it. In two additional sections along the shaft height, the upper unit is also leaning against the reinforced concrete shaft.

(b) The steam generator was re-evaluated for operation under seismic conditions. The steam generator vessel was reinforced and adjusted in order to enable installation and welding of hydraulic damping units. All the primary circuit components are deliberately designed for operation under seismic conditions supported by hydraulic damping units.

(c) The pressuriser is firmly fastened to the foundation and to the reinforced concrete walls on top, with the aid of four firm supports fixed as as a cross.

(d) All transverse and longitudinal tier shelves are firmly attached to the monolithic reinforced concrete.

(e) In the turbine hall, additional vertical and horizontal links have been made between the pillars and compound girders.

Safety fastenings of all wall panel constructions of the main building have also been added. All hydro-technical constructions are calculated on acceleration 0.2 g. Spent fuel storage pool and boron solution storage tank have a double liner of 8 and 4 mm of stainless steel respectively.

These improvements of plant resistance against seismic hazards, will necessarily result in a higher material inventory and larger volumes of dismantled materials. Hence it will also have consequences on the total decommissioning costs of the model 270 units.

2.4. TECHNICAL DESCRIPTION OF THE WWER-440 MODEL 213 REACTORS

The WWER-440/213 differs from the model 230 in that the model 213 has both an ECCS and connects a so called bubble-condenser tower to the accident localisation compartments of each unit in order to mitigate the effects of loss-of-coolant accidents. This model was designed to cope with a 500 mm pipe rupture. The reactor pressure vessel inside surface is cladded with stainless steel. Flywheels are incorporated into the primary coolant pumps in order to increase their coast down time during emergency situation.

The WWER-440/213 model has a variant that houses the nuclear steam supply system in a containment structure. There are two such units operating at Loviisa, Finland.

2.5. COMPARISON OF THE MATERIAL VOLUMES OF THE MODELS 230 AND 213 REACTORS

The types of the units included in the comparison are basically the same. However, there are significant differences in technological solutions, material volumes used in construction and as-built features that are important both for construction and decommissioning, and that should be considered in cost estimations for decommissioning. Table 2-2 summarises construction material volumes of WWER-440/230 and WWER-440/213 NPPs, relating to those plants that could provide reliable data.

Table 2-2. Typical construction material volumes of the WWER-440 twin units

Model		Material		
		Concrete (m^3)	Stainless steel (ton)	Carbon steel (ton)
WWER-440/230	Bulgaria Slovakia	110,000 117,449* 129,436**	8,000 5,306***	23,600 25,294***
WWER-440/213	Hungary Slovakia	160,000* 56,000** 220,579* 178,155**	9,200*** 5,914***	41,000*** 42,913***

* concrete over the level of -1 m
** concrete below the level of -1 m
*** inventory of technological equipment

3. WORKING APPROACH

3.1. OVERALL STUDY APPROACH

The data presented in this study are based on responses of participating Member States. A questionnaire was prepared and distributed among representatives of Member States operating WWER-440 NPPs or having such units in shutdown conditions or even in decommissioning. The questionnaire comprised (i) some general questions, (ii) a matrix to provide the estimated cost data and (iii) a series of questions to facilitate understanding of the answers to the cost matrix. The Member States were requested to provide the costs with an accuracy of at least 0.1 MUSD. In the cost matrix, a broad subdivision was made of decommissioning activities into tasks that may have to be executed for either immediate decommissioning or safe enclosure as referred to in the reference document [2]. In the referred document cost items related to activities that are carried out with a similar emphasis, whether or not tied to a similar time schedule for decommissioning, or that are based on overall activities that cannot be categorised in a specific time period, are grouped as follows:

01 Pre-decommissioning actions;

02 Facility shutdown activities;

03 Procurement of general equipment and material;

04 Dismantling activities;

05 Waste processing, storage and disposal;

06 Site security, surveillance and maintenance;

07 Site restoration, cleanup and landscaping;

08 Project management, engineering and site support;

09 Research and development;

10 Fuel and nuclear material;

11 Other costs.

The cost items are divided into several sub-items. In order to facilitate comparison of costs between decommissioning projects, for each cost item four cost groups have been defined: labour costs, investment costs (capital, equipment and material), expenses and contingency. It is noted that not all tasks necessarily need to be performed for all decommissioning projects.

For simplicity reasons and in order to facilitate comparison of data, it was agreed that the following general boundary conditions or aspects should be used in the study.

Financial conditions:

(a) All participating Member States use a fixed cost level and monetary conversion to USD, dated December 31, 1998. Exchange rates of national currencies and USD are shown in Table 3-1.

(b) For cost calculation the "current value method" [5] is used, as long term discounting of costs would distort the results due to the very different economical situations of the countries and the schedule of dismantling activities.

(c) Value Added Taxes (VATs) are only considered at the cost item "Taxes (11.0400)" if they exist at all.

(d)

Technical conditions:

(a) The units have been shutdown after normal operation, in accident free condition.

(b) In the scope of decommissioning, a WWER twin unit is included, the end goal being to return the site to a green or grey field status (grey field status differs from green field by the fact that after release from regulatory control the remaining buildings are not necessarily demolished).

(c) For decontamination, dismantling and waste processing only currently available methods are taken into account.

(d) At least 3 years cooling of the last fuel discharge is needed before shipment from the spent fuel pool to interim storage.

Social aspects:

(a) No social effects are considered beyond the owner's legal requirements.

Table 3-1. Exchange rates between USD and national currencies (on December 31, 1998)

Country	Exchange rate
Armenia	1 USD = 522.03 AMD
Bulgaria	1 USD = 1.80 BGL
Czech Republic	1 USD = 29.85 CZK
Finland	1 USD = 5.09 FIM
Germany	1 USD = 1.67 DEM
Hungary	1 USD = 220.12 HUF
Russian Federation	1 USD = 13.30 RUB
Slovakia	1 USD = 36.91 SKK
Ukraine	1 USD = 3.42 UAH

Some countries do not fully comply with the preliminarily determined boundary conditions. For specific countries, the reasons are as follows:

(a) Both units of the Armenian NPP were shut down in 1989, after the devastating 1988 earthquake. In view of the critical energy situation, in 1995 unit 2 was restarted and commercial operation resumed. The operational design lifetime for this reactor, as well as for the other models of WWER-440s, is 30 years. Unit 2 may be decommissioned before termination of its design lifetime if by the time the Armenian energy sector is provided with sufficient, adequate, diversified and secure sources of energy. Therefore, the considered decommissioning cost estimate has been prepared for two shutdown dates. The first option considers a shutdown date ahead of the scheduled design lifetime. The calculations for the second option were carried without considering the standby period from 1989 to 1995, resulting in an end of design lifetime up to the year 2010. Including the standby period from 1989 to 1995 would result in a possible operational period until 2015. As a result, costs differ due to the quantities of radioactive wastes that will be generated and to the amount of spent fuel.

(b) The German reference units (Greifswald NPP units 1 and 2) were stopped prematurely after 17 and 16 years of operation.

(c) In Bulgaria, Czech Republic, Finland and Germany, only decommissioning of the radioactive parts of the units have to be licensed. Decommissioning of other, non-radioactive parts of the units depends on the owner's decision.

The first replies from the Member States varied in the detail in which the cost figures were shown depending on the local circumstances. In order to be able to have a consistent and comparable cost database, it was decided to request for a review of the data. Rationale for this review were:

(a) To have a figure for each cost sub-item because in some cases costs were given at cost item level only. It was agreed to use the following terms:
   - "n.a." (not available) means that work is done within the scope of the project but the costs are not identifiable, i.e., in fact not available;
   - "0" means that there is no work done or costs incurred, i.e., cost is really zero;
   - "n.r." (not relevant) means that the cost item in question is not relevant (applicable) because, for instance, such costs do not arise in the kind of project considered.

(b) Cost figures were given in some cases that straddled over more than one cost item so that it was impossible to identify the cost figures explicitly for each item.

(c) To use the terms of cost groups like labour, investment, expenses and contingency as much as possible.

The participating institutes have revised and adjusted their cost data as completely as possible, making intelligent guesses where exact information was difficult to give. The new answers were fed into the matrix and served for analysis.

3.2. COUNTRY SPECIFIC APPROACHES

3.2.1. Armenia

To calculate many of its decommissioning costs Armenia used the Cost Estimating Computer Program (CECP). This model was originally developed for the USA Nuclear Regulatory

Commission in order to estimate the decommissioning cost of USA light-water reactors to the point of license termination. For most parts of the cost calculation the CECP uses algorithms based on unit cost factors. These cost factors consider non-productive times (work breaks, dressing and undressing times, training, etc.) and difficult working conditions (wearing respirators and working on scaffoldings), that increase the time required to perform a task.

Labour costs are calculated based on estimated time duration and required manpower to perform the decommissioning activities. As such, labour costs are not calculated based on annual salaries of an assumed number of decommissioning workers hired for an assumed number of years. In contrast, overhead costs (managers, supervisors, engineers, general plant technicians, clerks, etc.) are calculated on an annual basis. The labour costs are not reported separately in the study, however.

In addition to costs, the CECP also calculates man-hours, team-hours, and exposure-times associated with decommissioning. Operational radiation exposure calculations are based on Co^{60} only.

Two versions of the CECP are available: one for PWRs and one for BWRs. To model the ANPP, the PWR version of the CECP was reprogrammed in order to accommodate the 2-reactor, 12-steam generator configuration of the complete WWER-440 NPP. In addition, the units of measure were changed from the English to the International System (SI). Like the basic versions, the WWER version of the CECP calculates facility decommissioning costs only to the point of license termination; additional costs to return the area to a green field status are not defined.

As far as practicable, an attempt was made to account for differences in the economic conditions in the USA and Armenia. These conditions may be quantitatively characterised by several parameters: the cost of equipment and materials, the cost of structural materials, and labour productivity ratios. Several conversion factors were used in the CECP to convert these parameters from USA conditions to Armenian ones.

First of all, some of the conversions factors developed and used in the Joint Parallel Nuclear Alternative Study (JPNAS) were used to convert the cost estimates from USA to Armenian economic conditions. As an example, the following fractions of USA values were considered:

(a) Equipment: 0.70;

(b) Commodities (concrete and steel, average): 0.70;

(c) Labour productivity: 0.40;

(d) Cost of professional services: 0.15.

JPNAS factors were not used to calculate overhead (non-labour) costs. Instead, typical annual salaries for various Armenian professional, technical and clerical categories were converted to USD and then entered into the CECP, as indicated in Table 3-2.

When estimation the costs for different options, the sources [6], [7], [8] and [9] were used.

3.2.2. Bulgaria

In view of comparison, the decommissioning costs for the Bulgarian NPPs were defined based on data from:

(a) The Feasibility Study on decommissioning of units 1 and 2 of the Kozloduy NPP, completed by DECOM Sofia in 1997;

(b) The detailed Technical Project for decommissioning of Kozloduy NPP units 1-2, completed by Belgatom, Energiewerke Nord GmbH and ENPRO under the EC's PHARE Programme in 2001.

Table 3-2. Assumed values for various parameters in the CECP cost model

Parameter	Value
Monetary Unit	USD
Number of Shifts	Two 8-hour shifts/day
Laundry Services	2.50 USD/person-shift
Regulatory Costs	10,000 USD/year
Dry Active Waste Production Rate	1 compacted (5:1) 208 litre drum per crew per day
Normal Shutdown Power Consumption	4.52 MW
Cost of Electricity	0.02 USD/kWh
Electrical Power Consumption Rate during Safe Enclosure Periods	1 % of normal shutdown power consumption
Electrical Power Consumption Rate during Entombment Periods	0.2 % of normal shutdown power consumption
Small Tools and Minor Equipment	2 % of labour costs
Maintenance Allowance (for safe enclosure and entombment periods)	14,477 USD/year
Environmental Monitoring Costs	5,784 USD/year

The results of the Feasibility study are only used for some sub-items of the cost item "04 Dismantling activities" (04.1300, 04.1800, 04.1900, 04.2000, 04.2100, 04.2200) and for the cost item "07 Site restoration, cleanup and landscaping". The costs of the Feasibility Study were converted to the level of December 31, 1998 and were regrouped into prescribed cost items based on the reference document [2].

The costs originating from the detailed Technical Project for final shutdown, preparation of safe enclosure and safe enclosure stages are the actual costs from the cost calculations that were carried out under the project. The cost items/groups are in accordance with the reference document [2].

According to the Bulgarian approach:

- The costs of processing, packaging, transport, storage and disposal of the radioactive waste produced during plant operation are not part of the decommissioning costs;
- Resale of equipment is not considered;
- The costs to unload the last cores into the fuel pools as soon as possible after final shutdown, and to transfer the fuel after 3 years to the interim storage facility, are part of the decommissioning costs;
- In accordance with the safety regulations during decommissioning of nuclear facilities, final shutdown is the final stage of facility operations.

3.2.3. Czech Republic

The input data for the cost estimates used to prepare this document were taken from the Study for Decommissioning of the Dukovany NPP [10] elaborated in 1998 by the Czech company EGP Invest Uherský Brod. The costs were estimated for the decommissioning of four units, referring to the price levels of 1997. To compare the costs with the decommissioning costs of other WWER-440 NPPs, data were selected relating to the option safe enclosure of radioactive components for a period of 50 years. After this time period, complete dismantling of all radioactive components will be performed. This decommissioning methodology represents the strategy adopted by CEZ and was approved by the national regulatory body.

In order to estimate the decommissioning costs as indicated in the study, the entire decommissioning process was classified - in compliance with the technical part of the file - in separate decommissioning phases as preparation, safe enclosure, removal of material. Appropriate decommissioning activities as well as related costs were defined within the framework of these decommissioning phases. The costs for individual decommissioning activities were calculated, where possible, as the product of a number and the value of appropriate specific unit costs.

The cost estimates presented in the study were regrouped into the recommended cost items based on the reference document [2]. As the required cost estimates had to refer to a twin unit, the total costs were divided by a factor two.

Some specific comments have to be considered:

- Under cost item “01 Pre-decommissioning actions”, the sub-items 01.0300, 01.0400 and 01.0500 are included in the operational costs.
- Under “02 Facility shut down activities”, the Czech approach specifies that the removal of all radioactive materials from facility operations should be considered as operational costs (i.e., sub-items 02.0900, 02.1000 and 02.1100). The resale of facility equipment is not considered for sub-item 02.1300; this will be assessed during the development of the decommissioning plan.
- Within ”04 Dismantling activities”, no temporary waste storage area (sub-item 04.0900) will be built with respect to the boundary condition adopted for decommissioning. No decontamination is assumed prior to disassembly as part of decommissioning for sub-item 04.0100. Only decontamination of components after dismantling and decontamination of civil works is considered.
- Within “05 Waste processing, storage, disposal”, processing of system fluids, waste from decontamination and combustible material from facility operation (sub-items 05.0400, 05.0600 to 05.0700) are considered to be part of the operational costs. Storage of decommissioning waste (05.1500) is not considered due to the accepted boundary condition of decommissioning. Costs of waste disposal from facility operations (item 05.1100) and costs of decommissioning waste disposal (item 05.1600) are covered by other resources (nuclear account).
- In cost item “11 Other costs”, interest on borrowed money (11.0800) is not considered to be part of other costs. With respect to legislative regulations sufficient amount of money for decommissioning will be ensured.

3.2.4. Finland

The input data for the cost estimates used to prepare this document were taken from the studies that were accomplished in 1998 [11] and 1997 [12] by the Finnish companies Imatran Voima Oy and IVO Power Engineering Oy, today called Fortum Power and Heat Oy and Fortum Nuclear Services Ltd.

The decommissioning studies have been prepared for two basic options:

(a) Immediate decommissioning to grey field status, where only the radioactive parts will be dismantled. After shutdown of the power plant, the spent fuel will be stored at the plant for 20 years (this cooling time is needed for final deep geological disposal of the spent fuel). The site can be reused, e.g., for power production.

(b) Safe enclosure option followed by decommissioning to grey field status, where only the radioactive parts will be dismantled. Safe enclosure time will be 20 years. After shutdown of the power plant, the spent fuel will be stored at the plant for 20 years. The site can be reused, e.g., for power production.

The costs for both decommissioning options indicated in the study were calculated by normal methods that are widely used in the Fortum investment projects. As the cost groups identified in these methods (see also Annex 4) did not match those applied in the present comparison, the costs had to be regrouped. An expert evaluation had to be considered, and the costs had to be redistributed so that the final sum remained equal to the sum obtained with the basic methods used.

The large and heavy reactor components, e.g., reactor pressure vessels and steam generators, will be disposed of as such, without cutting into smaller parts. These large components are used as packages (barriers) for small equipment. This saves time, radiation dose and money.

Some further remarks on the decommissioning costs consider:

- Resale of facility equipment, etc., is not considered (sub-items 02.1300, 04.2400 and 11.0900).
- The costs in cost item “05 Waste processing, storage and disposal” are rather low as the repository is situated on site at a depth of about 110 m (this repository is already used for operational wastes of the power plant).
- Costs belonging to item “07 Site restoration, cleanup and landscaping” are not included in the decommissioning costs.
- Costs under “08 Project management, engineering and site support” are partly included in cost item “04 Dismantling activities”.
- Costs of “09 Research and development” are not included in the decommissioning costs but are considered under operational costs.
- No costs appear under sub-item 11.0800 (Interest on borrowed money) due to the existence of the own Nuclear Waste Management Fund.

Payments accomplished into the Nuclear Waste Management Fund are annually reviewed (because of inflation and changing waste input data) and modifications are performed when needed (see also Annex 4).

3.2.5. Germany

Shortly after the reunification of the German States, it was decided to decommission and dismantle all reactors on the Greifswald site. Due to the unplanned shutdown and the lack of collected funds in the previous East German State it was mandatory to establish a budget for decommissioning. Based on a preliminary technical concept and related cost estimate a budget commitment from the Ministry of Finance was established, giving only a framework for the activities and an upper limit for the decommissioning costs.

During project execution, the technical planning has advanced. Consequently, the basis for cost calculation is continuously improving and becoming more and more precise. Recalculation is performed at different levels of detail on a yearly, biannually and on a 5 year basis. The costs presented in this document for the Greifswald project are therefore the actual or nominal costs for the project.

The project includes the complete Greifswald site and it will be terminated when all artificial nuclides have been removed to such a level that exemption from the Atomic Law of Germany is achieved. This means that all costs related to the activities required to achieve this goal are part of the project.

On site are notably the following facilities that have to be treated: reactor units 1-4, that have been operated; reactor unit 5, that was under commissioning when shutdown; a wet spent fuel storage; different waste facilities; and all other facilities and areas where artificial contamination above release levels may be found. Furthermore all post-operational activities are included as well as treatment and disposal of all wastes and fuel on site, and the construction and operation on site of an interim storage for fuel, waste and dismantled materials. The necessary remarks to the list of cost items have been given in order to present transparent costs.

In order to obtain the costs for the decommissioning of a twin unit as required for this document, a very simple approach was adopted, i.e., the use of a factor 2/4.5. This was applied for all costs except for the mock-up testing in view of remote dismantling (sub-item 04.1100). This is obviously a very rough procedure, but taking into account all the costs as mentioned above, that are included in the project, the order of magnitude will be valid and the results may be used for comparison with other cost estimates.

It should be stressed that the costs presented for the Greifswald project are not comparable to cost calculations performed in the Federal Republic of Germany for funding purposes, where other boundary conditions were applied.

3.2.6. Hungary

The input data for the cost estimates used to prepare this document were taken from the study that was accomplished by DECOM Slovakia Ltd. in 1993 [13] and updated in 1997 [14].

The costs implied in the study [14] for both decommissioning options were classified along the cost coding system developed at the end of the 1950s and widely used in the investment practice in Hungary. The cost groups of this system are not matching those applied in the present comparison, however, and the costs had to be re-grouped. When re-grouping the costs, it had to be considered that the second version of the basic study is not dealing with a twin unit, but refers to the decommissioning all the four units on site.

As a result, for each cost code it had to be analysed whether the costs could be simply divided by a factor two, or whether reducing from four units to the twin version was not necessarily proportional with a reduction of the scope. As the costs in the study were provided at the 1997 level, they had to be converted to the mutually accepted level of 31 December 1998.

Only two of the main cost items could be clearly identified. For all others an expert evaluation had to be considered, and the costs had to be redistributed so that the final sum remained equal to the sum obtained after discounting and reducing the technical content to the twin version.

Some further remarks on the decommissioning costs are given:

(a) According to the Hungarian approach, costs of processing, packaging, transport and disposal of radioactive wastes produced during plant operations are part of the operational costs. For this reason, no cost figures are given under sub-items:

05.0600: Processing of waste from decontamination during facility operations;

05.0800: Processing of spent resins from facility operations;

05.0900: Processing of other nuclear and hazardous materials from facility operations;

05.1000: Storage of waste from facility operations;

05.1100: Disposal of waste from facility operations.

(b) As in many countries, also in Hungary most sub-items of the main cost group 10 (Fuel and nuclear material) are considered not to be part of the decommissioning costs.

(c) Sub-item 11.0100 (Owner costs) is in Hungary not included in a decommissioning cost calculation. Retraining of employees after ending power generation is the responsibility of the state.

(d) No costs were indicated for sub-item 11.0800 (Interest on borrowed money) as in Hungary the money will be available and no interests will have to be paid.

Though in Hungary some costs included in the cost item system of the reference document [2] are not part of the decommissioning costs, estimates are considered and available for those items for which fees have to be paid in the Central Nuclear Financial Fund (see also Annex 6.). Payments accomplished into the Fund are reviewed annually (because of the quickly changing circumstances and input data) and modifications are performed if needed. By evaluation these payments, the requirement of having transparent and clear calculations is put forward.

3.2.7. Russian Federation

The input data for the cost estimates used to prepare this document were taken from the studies prepared by VNIIAES in 1990 [15] and [16], 1994 [17], and 1998 [18] as well as from estimations of costs for radioactive waste disposal [19]. The decommissioning studies have been prepared for one basic option, i.e., decommissioning with safe enclosure under surveillance of the reactor and some highly contaminated components in the reactor building for 30 - 100 years. After the period of “safe enclosure under surveillance”, the nuclear unit will be decommissioned up to the grey field condition with simultaneous preparation of the site for reuse.

The costs evaluated in these studies were classified relating to a cost system that was adopted in the middle of the 80s and that was used in the former Soviet Union in investment practices for new constructions. The calculation was carried out for one unit, enabling the possibility of further operation of the other unit of a twin system, as well as operation of other units on site. As the cost groups of this system did not match those applied in the present comparison, the costs had to be re-grouped, which was only feasible at the level of the main cost group items.

The decommissioning process is broken down in four stages for which the costs are evaluated. Each stage may comprise the same kind of operations, e.g., decontamination, dismantling, processing of radioactive waste, etc. Some operations may inherently belong to only one stage. Each decommissioning stage therefore includes a list of all activities that need to be carried out and comprises a full evaluation of all related costs.

Based on these considerations, redistribution of the costs according to the recommended structure [2] required that the appropriate costs were selected from each decommissioning stage and summarised in the specific cost items if necessary.

3.2.8. Slovakia

The input data for the cost estimates used to prepare this document were taken from the studies that were accomplished as indicated in references [20, 21, 22]. In the feasibility studies for V1 NPP [20, 21], five decommissioning options were analysed:

1. Immediate and total dismantling after final shutdown.
2. Safe enclosure of the so called „hermetic area” (part of the reactor building) for each unit separately.
3. Safe enclosure of the reactor cavity with each reactor separately.
4. Safe enclosure of the entire reactor building.
5. NPP closing and storage under surveillance (Stage 1 according to the former IAEA classification).

For the purpose of this study, options 1, 2 and 5 were used.

The decommissioning study for V2 NPP has been prepared for three basic options [21]:

1. Complete decommissioning without safe enclosure, starting with termination of operations and ending with the unrestricted release of the site (immediate decommissioning to green field).
2. Decommissioning with 70 years safe enclosure of the reactor shaft and decommissioning to green field conditions after the safe enclosure period.
3. Decommissioning with closing under surveillance of the nuclear island for 70 years. After the “closing under surveillance” period the NPP is decommissioned up to green field.

The costs evaluated in the studies relating to the decommissioning options under reference were classified along the cost breakdown system that was developed at the end of the 50s and that was widely used in investment practices in the Slovakia. As the cost groups of this system did not match those applied in the present comparison, the costs had to be re-grouped. As the costs in the studies were provided at the 1991 and 1997 level respectively, they also had to be converted to the mutually accepted level of December 31, 1998. As the conversion for the V1 NPP was made in several steps, the uncertainty in the costs for V1 may be higher than in those for the V2 NPP.

In a first attempt, only two cost items could be clearly identified. For all others an expert evaluation had to be considered, and the costs had to be to be redistributed so that the final sum remained equal to the sum obtained before conversion. Some main cost items may have been over/underestimated, resulting in greater uncertainties.

It was decided, therefore, to recalculate all data in the model calculations, based on the building and technology inventory indicated in the above mentioned decommissioning studies, on adapted unit factors (for dismantling, decontamination, demolition, processing, packaging, disposal of waste, etc.) developed by DECOM Slovakia and on the principles of activity based costing. The model calculations were made for the:

∉# WWER 230 type, the immediate decommissioning option;

∉# WWER 230 type, the safe enclosure option for the reactor shaft only;

⋪# WWER 213 type, the immediate decommissioning option;

⋪# WWER 213 type, the safe enclosure option for the reactor shaft only.

The calculated costs are classified in three main categories:

a) Activity dependent costs (primary or secondary inventory, unit factors, correction factors);

b) Period dependent costs (staffing, time, time unit factors);

c) Fixed costs (fixed values).

The calculation structure is based on the Proposed Standardised List (PSL)[2]. Hence, the results are presented in the format of this structure. The inner structure of the costs for each calculated item follows the recommended cost category system (labour costs, capital costs, expenses and contingency).

The boundary conditions for the calculations originate from the currently accepted definition of activities considered in the decommissioning of the WWER NPPs V-1 and V-2 in the Slovakia:

a) The cooling period for the last fuel (part of the sub-item 02.0100) is not considered to be part of the decommissioning activities.

b) Treatment, storage, transport and disposal of radioactive wastes from operations (items 05.0400 to 05.1100) are not part of the decommissioning operations;

c) All items of the cost group “10 Fuel and nuclear material” and removal of spent fuel (part of the item 02.0200) are considered to be part of the fuel cycle.

d) The safe enclosure period is 30 years, in correlation with the planned deep geological repository;

e) The safe enclosure mode is a passive one, assuming limited surveillance and maintenance activities, considering the specific character of the area (security is supported by the availability of other NPP’s on site) and the relatively short safe enclosure period (extensive refurbishment of barriers during the enclosure period is not needed);

f) Assets from resale were not taken into account at this level of calculations (in fact they were not analysed).

g) In this first exercise, the four cases were calculated as isolated projects, without using any benefit from previous decommissioning activities.

Except for the above listed items, excluded by the boundary conditions, costs for all relevant items were calculated with the option to meet green field conditions (demolition to a level of -1 m and backfilling). The calculation results are considered to be preliminary values and represent the first estimates that were carried out in the Slovakia based on the Proposed Standardised List [2]. The model calculations are further tuned. A second version of the calculations will include the benefits of using some common characteristics of the area of the three NPPs A-1, V-1 and V-2:

⋪# Facilities for treatment, on-site temporary storage and transport of radioactive wastes from on-going decommissioning activities at the NPP A-1;

⋪# Experienced personnel that was trained during previous decommissioning activities;

⋪# Special decommissioning equipment (general, decontamination, and dismantling equipment, etc.) resulting from previous decommissioning activities;

∉# Results of previous research and development work;

∉# Benefits from the use of common areas and resources (to reduce security and maintenance costs).

The next set of optimised calculation results for all evaluated cases is expected to be available in the year 2003.

3.2.9. Ukraine

In a first phase, it was planned to construct three nuclear units at the site of the Rovno NPP. Units 1 and 2 (WWER-440 reactors) were put in commercial operation in 1981 and 1982, respectively. Unit 3 (WWER-1000 reactor) was commissioned in 1986. A further expansion of the plant (second phase) was scheduled with the construction of unit 4 (WWER-1000 reactor). The accident at the Chernobyl NPP in 1986 resulted in a moratorium on the construction of new nuclear units in Ukraine, however, and the construction of unit 4 was interrupted. When the moratorium was cancelled in 1994, the construction of unit 4 was continued. The difficult economic conditions in Ukraine hampered full accomplishment of the works so far; nevertheless, it is expected that unit 4 will be commissioned in 2003.

The WWER-440 units of the Rovno NPP have an initial design lifetime of 30 years. Closure may be expected in 2011 and 2012 but a lifetime extension for both units is under consideration. The future of the Rovno NPP will be determined by the following parameters:

(a) Lifetime extension of the first two units and their future decommissioning;

(b) Operation, lifetime extension and subsequent decommissioning of unit 3;

(c) Commissioning and operation of unit 4;

(d) Building and operation of the dry storage facility for spent fuel.

In future, the site will most likely continue to be reserved for power production purposes and this will certainly affect the decommissioning of the units 1-2.

A plan for the decommissioning of units 1-2 of the Rovno NPP, including cost estimation, is at the early stage of preparation. A conceptual planning is performed in the framework of the NPPs Decommissioning Concept of Ukraine. This concept is under development by the State Scientific Engineering Center of Control Systems and Emergency Response on behalf of the Ministry of Fuel and Energy of Ukraine. As a constituent part it includes the decommissioning cost estimations for the Ukrainian NPPs. An initial cost estimation was completed at the end of 1999. For the purpose of the present document, the existing data for units 1-2 were revised, completed, converted in the 1998 USD rate and presented in the form required by the reference document [2].

The approach used is based on the assumption that the pre-decommissioning activities on units 1-2 should start in 2006 after a decision is taken about the terms of a final shutdown without lifetime extension of both units. For the present study, the strategy of deferred decommissioning after safe enclosure during 30 years was elaborated. It was assumed that the decommissioning of both units is carried out sequentially, the activities in unit 2 starting after finalising the corresponding activities in unit 1.

Considering this assumption, a time schedule for the decommissioning activities at both units was developed. The methodology for estimating the decommissioning costs is based on unit prices for the various operations to be carried out in the assumed time schedule. Overall and specific costs were obtained either by assessment or by multiplication of the operational costs by appropriate factors. All unit costs, estimates and factors were obtained from experience acquired during the operational period. The cost evaluations for waste processing were based on unit prices for standard waste in Ukraine and on estimates for special waste.

The result is a preliminary cost estimate for the decommissioning strategy, that should be recommended for the units 1-2 of the Rovno NPP. It is necessary to indicate that the data based on which costs and time schedule have been elaborated are to a great extent uncertain and that a detailed study should be carried out.

4. RESULTS AND ANALYSIS OF THE COST ESTIMATES

In accordance with the cost item structure established in the reference document [2], the cost data are summarised in Tables 4-1 to 4-22. Amongst the participating Member States, Bulgaria, Czech Republic, Russian Federation and Ukraine did not deliver data for the option of immediate decommissioning, neither did Germany for the safe enclosure option. From the tables, it became also clear that some of the participating organisations were unable to provide figures for all the cost items. In some cases one of the reasons was that the specific activity was accomplished in a contractual form.

4.1. SCOPE OF THE COST ITEMS

The geographical distribution of the reference units does not suggest that any additional transport costs, neither any further expenditures should be included due to possible extreme weather conditions, not even in the Russian Federation, as the Russian reference units are located in the European part of the country.

4.1.1. Pre-decommissioning actions

In practice, in all countries pre-decommissioning activities for WWER-440 NPPs started with the preparation of various preliminary studies. The scope and type of the available dismantling documents are largely different. There are preliminary studies, cost assessments as well as technical concepts. In most countries, their compulsory legal revision cycle varies between 2 to 5 years.

For the purpose of preliminary planning, for some sites “Radiological surveys for planning and licensing, (01.0300)” and “Hazardous material surveys and analysis, (01.0400)” were accomplished, and even repeated. In some countries operational radiological protection measures and international reference data are used as a basis for preliminary studies.

Today, a final and licensed decommissioning plan is only available in Germany where decommissioning of the Greifswald NPP began in 1995. In principle, in all countries the content of the final decommissioning plan will comply with the requirements of the IAEA [23, 24]. It is a common principle in the area of regulations that a final decommissioning plan should be completed at least 5 years before starting the decommissioning activities and that it should be submitted to the competent national authority.

The inventory of active and non-active materials was in general defined based on the available design and construction data and on on-site measurements. Considering the significant deviations between input data, it is suggested that an improved inventory should be developed during preparation of the final decommission plan. In Hungary, it is considered that CAD files that are repeatedly created for the various safety analyses will be very useful for preparing the accurate quantitative definitions that are required for developing the final decommissioning plan.

A general uncertainty in cost estimations results from the fact that actual activation in concrete structures or actual amounts of contaminated concrete due to casual leakage, i.e. the actual amount of radioactive concrete waste, may only be determined by sampling and analyses after the units have been finally shutdown. Only in some cases, concrete was sampled in association with enhancement of leak tightness, but the resulting concrete pieces were not always analysed for their isotopic composition.

Another uncertainty may result from the potential contamination of secondary systems located in the turbine hall. The actual amount of this contamination as well, may only be determined after the units have been finally shutdown and completely emptied.

It is reminded that within the preparatory activities, it is confirmed that emphasis has been put on the required calculations to define the necessary funding (payments) that had to be collected in the financial provisions established in most countries. In some countries, the money to be provided has been defined as a fix percentage of the price of electrical energy production. In countries like Czech Republic, Finland and Hungary, these calculations are reviewed in time periods of 1-5 years and the input data that provide the basis for the calculations are actualised as well.

Costs resulting from public consultations or public hearings are taken into account when relevant.

4.1.2. Facility shutdown activities

The activities under this cost item are routine operations for which expenditures could be relatively accurately calculated, taking into account the personnel needed for running the organisation, the time schedule and the average wages. They are performed in any option considered in the study immediately after shutdown of the operations.

The time required for these activities (for one unit) varies between 3 and 5 years depending on the interim spent fuel storage technology. In case of WWER-440 reactors, defueling and transfer of fuel to temporary spent fuel storage always means transfer to the spent fuel pool of the units.

The sub-item “Removal of special system fluids (D_2O, sodium, etc.) (02.0600)” is not relevant in case of WWER–440 NPPs as there are no such special system fluids.

Facility shutdown activities also include the removal of various operational wastes from the units. It is interesting to mention that in some cases the authorities regulated the maximum volumes of radioactive waste that could be stored on site. As a result, the costs for the removal of operational wastes do not always include the costs for the total amount of wastes that are produced during the operational period of the plant.

Currently, many plants have not examined which systems should be kept in operation after shutdown and transfer of fuel to intermediate storage.

At the end of the shutdown period, spare parts and equipment that are inactive or only slightly contaminated but in good condition, could be offered for sale on the market. Types and amount of such items are difficult to estimate at an early planning stage, however. Therefore, in many countries, these questions have not yet been examined.

4.1.3. Procurement of general equipment and material

According to the reference document [2], this main cost item includes the following sub-items:

(a) General site dismantling equipment, (03.0100);

(b) General equipment for personnel/tooling, (03.0200);

(c) General radiological protection and health physics equipment, (03.0300); and

(d) General security and maintenance equipment for long-term storage, (03.0400).

As for general site-dismantling equipment, either the organisation assigned to manage the decommissioning operations or the casual subcontractors may provide it. It is also probable that some of the expensive equipment could be leased, which would be the more economical solution. For radiological protection and health physics equipment a change in every 15 years is considered due to wear and outdating. Costs of security and maintenance equipment are different for the examined decommissioning options.

4.1.4. Dismantling activities

In general, the dismantling activities are among the most expensive items of any decommissioning project. The high cost items within the 24 sub-items are for WWER-440 NPPs:

(a) Decontamination of areas and equipment in buildings to facilitate dismantling, (04.0100);

(b) Dismantling operations on reactor pressure vessel and internals, (04.1200);

(c) Removal of primary and auxiliary systems, (04.1300);

(d) Removal of biological/thermal shield, (04.1400);

(e) Removal and disposal of asbestos, (04.1600);

(f) Building decontamination, (04.1800);

(g) Decontamination for recycling and reuse, (04.2200).

One of the most complicated dismantling activities, affecting the highest radiation exposure as well, is the removal of the reactor pressure vessel and its internals. Basically two solutions are available. The first and less expensive one, also resulting in the lowest exposure, is as planned in Finland where the reactor pressure vessel and its internals will be removed in one piece and buried in an underground (geological) repository.

Another possible solution, adopted by other countries is on-site cutting, packaging, interim storage and later disposal. Currently, remote controlled tooling needed to cut the vessels and the internals have been developed in Germany. It is expected that such specific remote controlled equipment may not only be used in immediate decommissioning but even in the safe enclosure option. For the removal of primary and auxiliary systems, the methods described in [25] may be generally used.

When dismantling technological systems, components are normally cut down to pieces of 0.5-1.0 m or 200–500 kg, respectively, depending on the requirements for waste and material management. Currently, technologies dealing with the biological shield of WWER-440 units have only been developed in Germany. For the model 230, biological protection is provided by a water tank; for the model 213, however, there is a dry protection in heavy concrete.

In Finland, it was estimated that around the reactor an activated concrete layer of about 1.2 m thick should be considered. This area needs further examination, even though it would prove that the activated volume could be higher. It can only be defined by analysing samples taken from the concrete, as mentioned in Section 4.1.1.

4.1.5. Waste processing, storage and disposal

In some countries the accepted starting point of decommissioning is when no operational wastes are left in the facility. Only costs of handling and processing waste materials from decommissioning activities are considered to be part of decommissioning costs. Radioactive waste generated during operations should be continuously processed. In general it can be stated that in each country efforts are directed to reduce the amount and the volume of wastes.

For packaging, metallic 200 and 400 litre drums, ISO containers and concrete boxes of various dimensions are used. In some countries, processing of liquid wastes was not yet started; only concentrating of waste waters is considered. As a result, not much information is available referring to applied waste management options. Volumes of operational wastes vary between wide limits. It is considered that only limited information is available referring to both the investment costs and the environmental impact assessment of the facilities that are required in most countries.

In case of identical radiological conditions, the waste management costs are higher for model 213 because of its higher material inventory.

Recycling, unconditional release and reuse of dismantled materials is applied at large scale in the Greifswald project.

Storage for unconditioned waste materials is in most cases available and is sometimes common to several units on a site. In some countries also so-called “national” storage or disposal sites exist. Large scale decommissioning activities may require that additional storage or disposal areas for conditioned radioactive waste are available, which may have a major impact on the decommissioning costs.

4.1.6. Site security, surveillance and maintenance

According to the reference document [2], this main cost item includes the following activities relating to decommissioning and safe enclosure:

(a) Site security operation and surveillance, (06.0100);

(b) Inspection and maintenance of buildings and systems in operation, (06.0200);

(c) Site upkeep, (06.0300);

(d) Energy and water, (06.0400);

(e) Periodic radiation and environmental survey, (06.0500).

For cost estimation, operational, maintenance and periodical controls and energy supply are considered as well as spare parts that are absolutely required at these activities. Costs are proportional to the period of time during which the activities are performed.

Relating to the “Periodic radiation and environmental surveys” that have to be performed during safe enclosure activities, the frequency and scope of inspections are currently in most countries not regulated. This may cause significant variations in data.

In this phase of decommissioning, electricity is the most important type of energy used. Electricity prices vary from country to country, going from 0.02 to 0.08 USD/kWh.

4.1.7. Site restoration, cleanup and landscaping

“Demolition or restoration of buildings (07.0100)” is the most important cost item within this cost group. Buildings (including activated ones) are decontaminated and demolished (only if required), generally down to about 1.0 m deep. Some technical differences between WWER-440 models may exist. For dismantling the “balance of plant” systems and building components, various site-specific solutions may be used, e.g., for the condenser cooling systems, etc. In case of immediate decommissioning, all technological buildings are demolished if required. Concrete debris may be suitable for backfilling of voids and cavities, or may be recycled in the non-nuclear industry.

4.1.8. Project management, engineering and site support

The final selection of an eventual main contractor is the responsibility of the organisation that is assigned to manage the decommissioning project. This could be a newly established organisation or an organisation derived from the former operator.

Even though in most countries the nuclear liability belongs to the operator, the management of the decommissioning project and the organisational structure during decommissioning have not always been defined yet. As a result, the scope of work to be distributed between the responsible organisation and the potential subcontractor(s) has not yet been specified.

4.1.9. Research and development

According to some considerations, all technologies and equipment that are necessary to decommissioning a NPP are currently available, and could be purchased on the market. Consequently, there should be no need for any research and development activity. Others, however, consider that research and development have not yet been completed, even not at the smaller scale, and that there is a continuous need to make progress in this area. Research and development may be funded from other sources, however.

Further unit-specific research and development work for WWER-440 reactors may be seen in the area of activation of the reactor pressure vessel and its biological shield. The results may be used to define the disposal option for the reactor pressure vessel and to get a more accurate view on the concrete volumes that have to be handled as radioactive waste.

4.1.10. Fuel and nuclear material

Once removed from the units, spent fuel follows a separate routing. Handling of spent fuel is practically independent from the chosen decommissioning option. Almost all participating countries follow the internationally accepted concept of interim storage. Final decision on spent fuel disposal is pending. The storage capacity of the spent fuel pools of a typical WWER-440 NPP is about 8 years, even with the so called close spaced technology. From here, the operators have to transfer the cooled assemblies to an interim spent fuel storage. The type and capacity of such a storage facility may differ from one country to another. Similar to the construction costs of an interim storage facility, the dismantling costs may be proportional to the size of the facility. They will also depend on the type of the facility, being a wet or a dry storage unit.

4.1.11. Other costs

Expenditures under “Owner costs, (11.0100)” - items like staff reduction, re-assignment/-training, key employee retention/incentive programmes - are emerging either at operator or at state level, and may be part of the decommissioning costs.

An exact determination of the various "Taxes, (11.0400)" is essential as in some participating countries the value-added tax (VAT) reaches the 15 % limit. In the cost item “Contingency, (11.0700)”, no reserves were considered, except Hungary and Slovakia, neither for inflation nor for escalation of high-risk cost elements.

Member States will not finance their decommissioning costs based on loans. As a result, no interest charges are considered.

4.1.12. Cost categories

Each cost item may be divided into cost categories in order to specify the nature of the cost. According to the reference document [2] for each cost item, four cost categories may be defined:

- Labour costs;
- Capital, equipment and material costs (investment costs);
- Expenses;
- Contingency.

It has been generally accepted that the decommissioning of a NPP is a labour intensive task. According to a previous study [26] labour represents about 56 % of the total decommissioning costs, and capital, equipment and material costs as well as expenses both contribute for 22 % to the total decommissioning costs. The same document recommends a general contingency of 10 %. This usually has not been considered in the current study, however.

4.2. COSTS FOR IMMEDIATE DECOMMISSIONING

Only Germany and Finland have definitely selected a strategy of immediate decommissioning. Armenia, Hungary and Slovakia have calculated the costs for the option of immediate decommissioning as well. As a result, five countries provided cost data. Slovakia provided data both for models 230 and 213.

4.2.1. Costs of pre-decommissioning actions

Costs of pre-decommissioning actions are shown in Table 4-1. The differences in planning costs for decommissioning (sub-item 01.0100) are not significant though labour costs in Germany are much higher than in Hungary or in the Slovakia.

In many countries, uncertainties prevail about licensing activities. Currently, for many projects no proper information is available on the exact costs relating to authorisation. During the operational period, these expenses are mostly related to the electricity generated by the facility. During decommissioning, however, and with the spent fuel removed, another regulatory authority may take over. As a result, licensing or authorisation costs are only rough estimates, except for Germany where the comparatively high costs are based on real figures.

For Hungary, the cost figure for sub-item “Prime contracting selection (01.0500)” is lower than the 0.1 MUSD limit, that was commonly established as the accuracy limit.

Except for Armenia, where the costs of pre-decommissioning actions were collected under Project Management Expenditures, and for Germany where the costs for licensing are very high, differences between the other data are limited to 1.8 MUSD, which is less than 1 % of the average total cost.

From the detailed data it may be seen, that labour cost is the dominating cost category.

Table 4-1. Costs of pre-decommissioning actions (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
01.0100	Decommissioning planning	Labour costs			3.63		3.40	3.63
		Capital			0.44		0.00	0.44
		Expenses			0.73		0.70	0.73
		Contingency			0.48		0.50	0.48
		Subtotal	n.a.	5.16	5.28	n.a.	4.60	5.28
01.0200	Authorisation	Labour costs			0.67		1.90	0.67
		Capital			0.08		0.00	0.08
		Expenses			0.13		0.40	0.13
		Contingency			0.09		0.30	0.09
		Subtotal	n.a.	23.69	0.97	n.a.	2.60	0.97
01.0300	Radiological surveys for planning and licensing	Labour costs			0.49		0.60	0.49
		Capital			0.06		0.20	0.06
		Expenses			0.10		0.50	0.10
		Contingency			0.06		0.20	0.06
		Subtotal	n.a.	0.44	0.71	n.a.	1.50	0.71
01.0400	Hazardous-material surveys and analysis	Labour costs			0.22		0.30	0.22
		Capital			0.03		0.10	0.03
		Expenses			0.04		0.10	0.04
		Contingency			0.03		0.00	0.03
		Subtotal	n.a.	0.10	0.32	0.00	0.50	0.32
01.0500	Prime contracting selection	Labour costs			0.09			0.09
		Capital			0.03			0.03
		Expenses			0.02			0.02
		Contingency			0.01			0.01
		Subtotal	n.a.	0.00	0.15	n.a.	b)	0.15
Total:			a)	29.39	7.43	7.40	9.20	7.43

a) Included into 08.0200
b) The cost is less than 0.1 MUSD

4.2.2. Costs of facility shutdown activities

This cost item includes 13 sub-items, from which the following are the most interesting and also the most expensive ones:

(a) Plant shutdown and inspection (02.0100);

(b) Sampling for radiological inventory characterisation (02.0400);

(c) Decontamination of systems for dose reduction (02.0700);

(d) Asset recovery: Resale of facility equipment and components as well as surplus inventory to other licensed and unlicensed facilities (02.1300).

For some other reactor types defueling costs (sub-item 02.0200) may represent about 5-10 % of the total decommissioning costs. For WWER-440 NPPs the costs connected to this item are both from the technological and from the financial point of view very small, and may be neglected relating to the total decommissioning costs, as well as the following items:

(a) Drainage and drying or blow down of all systems not in operation (02.0300);

(b) Removal of system fluids (water, oils, etc.) (02.0500);

(c) Removal of waste from decontamination (02.0800);

(d) Removal of combustible material (02.0900);

(e) Removal of spent resins (02.1000);

(f) Removal of other waste from facility operation (02.1100);

(g) Isolation of power equipment (02.1200).

Some countries simply included the costs of the above mentioned items in "Plant shutdown and inspection (02.0100)". This was done as a major part of these activities is carried out by the same personnel (control room and field operators in the primary circuit). The same team also supervises the cooling of the spent fuel assemblies stored for 3-5 years in the decay pools and guarantees nuclear safety during the shutdown period of the facility. As this staff needs to be on site until all spent fuel assemblies have been removed to interim storage, irrespective of their engagement during working hours, it is practical to use their skills to accomplish the above mentioned activities during the available working time.

4.2.2.1. Plant shutdown and inspection

In case of Germany, this sub-item is remarkable high, which can be explained by the fact that:

(a) Labour costs are much higher in Germany than in the other countries;

(b) The scope of work is extended by a few items, amongst which the more significant are:

- Post-operational and site operation activities until the end of the project including operation of all site utilities, maintenance and major parts of the radiological protection work. As a result of the unplanned shutdown, these activities took an excessively long time period before decommissioning could be started (about 5 years).
- “Sampling for radiological inventory characterisation (02.0400)”;
- “Processing of waste from decontamination during facility operations (05.0600)”;

Table 4-2. Costs of facility shutdown activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
02.0100	Plant shutdown and inspection	Labour costs			0.48		43.10	0.48
		Capital			0.07		1.00	0.07
		Expenses			0.24		2.70	0.24
		Contingency			0.08		5.60	0.08
		Subtotal	n.a.	508.75	0.87	n.a.	52.40	0.87
02.0200	Removal of fuel and/or nuclear fuel materials	Labour costs			0.22			0.22
		Capital			0.03			0.03
		Expenses			0.04			0.04
		Contingency			0.03			0.03
		Subtotal	n.a.	13.07	0.32	n.a.	a)	0.32
02.0300	Drainage and drying or blow down of all systems not in operation	Labour costs			0.13			0.13
		Capital			0.02			0.02
		Expenses			0.03			0.03
		Contingency			0.02			0.02
		Subtotal	n.a.	a)	0.20	n.a.	a)	0.20
02.0400	Sampling for radiological inventory characterisation after plant shutdown, defueling and drainage and drying or blow down of syst.	Labour costs			0.46		1.40	0.46
		Capital			0.06		0.00	0.06
		Expenses			0.15		0.20	0.15
		Contingency			0.07		0.20	0.07
		Subtotal	n.a.	a)	0.74	n.a.	1.80	0.74
02.0500	Removal of system fluids (water, oils, etc.)	Labour costs			0.13			0.13
		Capital			0.02			0.02
		Expenses			0.03			0.03
		Contingency			0.02			0.02
		Subtotal	1.12	b)	0.20	n.a.	a)	0.20
02.0600	Removal of special system fluids (D2O, sodium, etc.)	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
02.0700	Decontamination of systems for dose reduction	Labour costs			0.16		1.80	0.16
		Capital			0.02		0.30	0.02
		Expenses			0.08		1.00	0.08
		Contingency			0.03		0.40	0.03
		Subtotal	2.96	2.27	0.29	n.a.	3.50	0.29

(cont.)

Table 4-2. Costs of facility shutdown activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
02.0800	Removal of waste from decontamination	Labour costs			0.04		0.40	0.04
		Capital			0.01		0.00	0.01
		Expenses			0.04		0.10	0.04
		Contingency			0.01		0.10	0.01
		Subtotal	n.a.	a)	0.10	n.a.	0.60	0.10
02.0900	Removal of combustible material	Labour costs			0.03			0.03
		Capital			0.00			0.00
		Expenses			0.01			0.01
		Contingency			0.00			0.00
		Subtotal	n.a.	a)	0.04	0.00	a)	0.04
02.1000	Removal of spent resins	Labour costs			0.02			0.02
		Capital			0.00			0.00
		Expenses			0.00			0.00
		Contingency			0.00			0.00
		Subtotal	n.a.	a)	0.02	n.a.	a)	0.02
02.1100	Removal of other waste from facility operation	Labour costs			0.03			0.03
		Capital			0.00			0.00
		Expenses			0.01			0.01
		Contingency			0.00			0.00
		Subtotal	n.a.	a)	0.04	0.00	n.r.	0.04
02.1200	Isolation of power equipment	Labour costs			0.16			0.16
		Capital			0.02			0.02
		Expenses			0.03			0.03
		Contingency			0.02			0.02
		Subtotal	n.a.	a)	0.23	n.a.	a)	0.23
02.1300	Asset recovery: Resale of facility equipment and components as well as surplus inventory to other licensed ……..	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	-33.30	n.a.	0.00	0.00	n.a.
Total:			4.08	490.79	3.05	31.40	58.30	3.05

a) Included into 2.0100

b) Included partly into 2.0100 and partly into 5.0400

In the case of the Slovakia, the costs for the cool down period are not included in decommissioning cost item 02.0100, but the figures are estimated and are similar to the Hungarian ones.

Comparing to earlier considerations, the plant shutdown and inspection period could be shorter, as currently the storage time for the last loaded fuel assemblies in the decay pools could be shortened. Instead of the earlier accepted 5 years, 3 years for one unit could be sufficient.

4.2.2.2. Sampling for radiological inventory characterisation

For this cost item, only the Hungarian and Slovakian data could be compared. The related deviation seems acceptable.

4.2.2.3. Decontamination of systems for dose reduction

In this option, the entire primary circuit should be decontaminated. When evaluating such a decontamination of the primary circuit and the related systems, the following technologies have been considered:

Armenia: Chemical decontamination;

Finland: Normal chemical decontamination (e.g., first stage with NaOH + $KMnO_4$-solution, second stage with oxalic acid solution);

Germany: Chemical decontamination (as indicated for Finland) and electrolytic (oxalic acid) method;

Hungary: Two stage decontamination process with alkaline solution of potassium permanganate and with solution of oxalic or citric acids;

Slovakia: Chemical decontamination.

4.2.2.4. Asset recovery: Resale of facility equipment and components as well as surplus inventory to other licensed and unlicensed facilities

Only Germany provided data referring to “Asset recovery (02.1300)”. It should be seen as a general principle that sale of equipment that is still in acceptable conditions is not rejected for any reference unit. It is difficult to assess such possibilities, however. Such revenues, if any, may be part of the general reserves for contingencies.

4.2.3. Costs of procurement of general equipment and material

The results of this cost group are indicated in Table 4-3. Considering that the German costs of sub-item “General equipment for personnel/tooling for decontamination (03.0300)” are included in the plant shutdown and inspection costs, expenditures for this item are nearly at the same level. The sub-item “General security and maintenance equipment for long term storage (03.0400)” may in this case be considered for long term decommissioning activities.

The higher costs for the item 03.0300 in the Slovakia case represent the equipment for monitoring material release and for innovation of the radiological protection systems.

Table 4-3. Costs of procurement of general equipment and material (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
03.0100	General site dismantling equipment	Labour costs			0.05		0.00	0.05
		Capital			1.11		6.10	1.11
		Expenses			0.01		0.00	0.01
		Contingency			0.12		0.70	0.12
		Subtotal	3.50	7.11	1.29	n.a.	6.80	1.29
03.0200	General equipment for personel/tooling decontamination	Labour costs			0.03		0.00	0.03
		Capital			0.14		1.50	0.14
		Expenses			0.01		0.00	0.01
		Contingency			0.02		0.20	0.02
		Subtotal	0.50	a)	0.20	n.a.	1.70	0.20
03.0300	General radiation protection and health physics equipment	Labour costs			0.44		0.00	0.44
		Capital			4.66		0.80	4.66
		Expenses			0.09		0.00	0.09
		Contingency			0.52		0.10	0.52
		Subtotal	n.a.	3.78	5.71	n.a.	0.90	5.71
03.0400	General security and maintenance equipment for long term storage	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Total:			4.00	10.89	7.20	8.20	9.40	7.20

a) Included into 2.0100

4.2.4. Costs of dismantling activities

The costs for the dismantling activities are shown in Table 4-4. As the dismantling costs may amount up to 13 – 43 % of the total costs, significant expenditures are included here. The data also show large deviations.

The sub-item "Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy (04.0500)" is important only in the case of deferred decommissioning.

In some cases there is a need to establish a temporary waste storage area including adaptation of existing buildings (sub-item 04.0900). At many sites this question is not resolved, and a final decision whether and where it has to be established will only be taken in the framework of the detailed dismantling schedule. In order to prepare such decision, local material transport routes have to be analysed and designed.

For sub-item "Removal of biological/thermal shield (04.1400)" it could be evaluated that dismantling of the water tank as the biological shield of the model 230 should be cheaper.

In the case of the Slovakia where costs for both reactor models were estimated, the differences result from the higher technological inventory of the 213 model.

Only Germany and Hungary provided data referring to “Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycling or reuse (04.2400)”. Although the figures show the same order of magnitude, the existing differences may be understood as follows:

(a) Two different reactor types are compared with quite different volumes;
(b) The efficiency of the proposed decontamination technologies is different;
(c) Clearance criteria are different;
(d) Prices of metals and other materials are also different.

4.2.5. Waste processing, storage and disposal costs

Estimated volumes of conditioned low/intermediate level decommissioning waste (L/ILW) are shown in Figure 4-1. Major portion of high-level decommissioning waste (HLW) is spent fuel and is not part of this document. The related cost data are summarised in Table 4-5. Expenditures of waste handling for this decommissioning option amount up to 20 - 42 % of the total costs.

Comparison of the costs is hampered by the fact that in some countries, e.g., in Bulgaria, Czech Republic and Hungary, processing, packaging, transport and storage of operational wastes is part of the operational costs. It is a condition for starting the decommissioning phase when the production of electricity was ended that only the operating systems could be in a ‘loaded’ state. Only the processing/treatment costs for these so-called ‘last loads’ could be included in the cost item “Processing of system fluids (water, oils, etc.) from facility operations (05.0400)”. Before decommissioning operations are started, all previously produced wastes should be removed.

Other countries denoted for the cost item “Processing of waste from decontamination during facility operations (05.0600)” the indication “n/a”. In WWER–440 NPPs, waste waters of various origin are produced during operation that get mixed. It is difficult to identify whether certain waste waters result from discharges of technological systems or whether they result from any decontamination activity. In the first case they have to be referenced under the sub-item “Processing of system fluids (water, oils, etc.) from facility operations (05.0400)”; in the latter case they have to be included in cost item 05.0600.

Table 4-4. Costs of dismantling activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
04.0100	Decontamination of areas and equipment in buildings to facilitate dismantling	Labour costs		1.30	1.41		1.50	1.41
		Capital		0.60	0.98		0.20	0.98
		Expenses		0.20	0.28		0.80	0.28
		Contingency			0.27		0.30	0.27
		Subtotal	n.a.	2.10	2.94	n.a.	2.80	2.94
04.0200	Drainage of spent-fuel pool and decontamination of linings	Labour costs			0.11		0.00	0.11
		Capital			0.07		0.00	0.07
		Expenses			0.03		0.10	0.03
		Contingency			0.02		0.00	0.02
		Subtotal	n.a.	a)	0.23	n.a.	0.10	0.23
04.0300	Preparation for dormancy	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
04.0400	Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
04.0500	Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
04.0600	Site reconfiguration, isolating and securing structures	Labour costs		8.40	1.03		0.00	1.03
		Capital		3.20	0.13		0.00	0.13
		Expenses		10.00	0.26		0.00	0.26
		Contingency			0.14		0.00	0.14
		Subtotal	n.a.	21.60	1.56	n.a.	0.00	1.56
04.0700	Facility (controled area) hardening, isolation or entombment	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.

(cont.)

Table 4-4. Costs of dismantling activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
04.0800	Radiological inventory characterisation for decommissioning and decontamination	Labour costs		1.02	0.17		1.50	0.17
		Capital		0.00	0.19		0.10	0.19
		Expenses		0.09	1.70		0.30	1.70
		Contingency			0.21		0.20	0.21
		Subtotal	n.a.	1.11	2.27	n.a.	2.10	2.27
04.0900	Preparation of temporary waste storage area	Labour costs		0.18	0.08		0.10	0.08
		Capital		0.10	0.07		0.10	0.07
		Expenses		0.80	0.03		0.10	0.03
		Contingency			0.02		0.00	0.02
		Subtotal	n.a.	1.08	0.20	n.a.	0.30	0.19
04.1000	Removal of fuel-handling equipment	Labour costs			0.14			0.14
		Capital			0.10			0.10
		Expenses			0.03			0.03
		Contingency			0.03			0.03
		Subtotal	n.a.	a)	0.30	n.a.	0.05	0.29
04.1100	Design, procurement, and testing of special tooling/ equipment for remote dismantling	Labour costs		11.10	0.54		0.00	0.54
		Capital		41.80	2.18		5.60	2.18
		Expenses		10.70	0.11		0.10	0.11
		Contingency			0.28		0.70	0.28
		Subtotal	n.a.	63.60	3.11	n.a.	6.45	3.11
04.1200	Dismantling operations on reactor vessel internals	Labour costs		7.07	1.74		2.00	1.74
		Capital		1.33	0.63		0.40	0.63
		Expenses		3.33	0.35		1.00	0.35
		Contingency			0.27		0.40	0.27
		Subtotal	0.10	11.73	2.99	n.a.	3.80	2.99
04.1300	Removal of primary and auxiliary systems	Labour costs		40.71	11.15		36.90	14.48
		Capital		4.89	2.69		6.80	3.49
		Expenses		5.91	2.30		6.80	2.98
		Contingency			1.61		6.50	2.10
		Subtotal	24.00	51.51	17.75	n.a.	57.00	23.05
04.1400	Removal of biological/ thermal shield	Labour costs		1.20	0.09		0.30	0.09
		Capital		0.00	0.01		0.20	0.01
		Expenses		0.62	0.02		0.50	0.02
		Contingency			0.01		0.10	0.01
		Subtotal	0.20	1.82	0.13	n.a.	1.10	0.13

(cont.)

Table 4-4. Costs of dismantling activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
04.1500	Removal of other material/ equipment from containment structure and all other facilities, or removal of entire contaminated facilities	Labour costs		5.56	4.25		3.60	4.25
		Capital		0.76	0.51		0.40	0.51
		Expenses		0.67	0.89		0.30	0.89
		Contingency			0.57		0.50	0.57
		Subtotal	0.30	6.99	6.22	n.a.	4.80	6.22
04.1600	Removal and disposal of asbestos	Labour costs		3.07	0.11		1.00	0.11
		Capital		0.18	0.01		1.50	0.01
		Expenses		0.53	0.02		1.00	0.02
		Contingency			0.01		0.40	0.01
		Subtotal	n.a.	3.78	0.15	0.00	3.90	0.15
04.1700	Removal of pool linings	Labour costs			0.18		0.40	0.18
		Capital			0.04		0.20	0.04
		Expenses			0.04		0.30	0.04
		Contingency			0.03		0.10	0.03
		Subtotal	n.a.	b)	0.29	n.a.	1.00	0.29
04.1800	Building decontamination	Labour costs		7.47	1.25		2.80	1.25
		Capital		5.78	0.15		0.90	0.15
		Expenses		4.09	0.28		1.40	0.28
		Contingency			0.17		0.60	0.17
		Subtotal	1.90	17.34	1.85	n.a.	5.70	1.85
04.1900	Environmental cleanup	Labour costs		0.62	0.35		2.50	0.35
		Capital		0.00	0.04		0.60	0.04
		Expenses		0.18	0.07		0.50	0.07
		Contingency			0.05		0.40	0.05
		Subtotal	n.a.	0.80	0.51	n.a.	4.00	0.51
04.2000	Final radioactivity survey	Labour costs			2.05		1.20	2.05
		Capital			0.25		2.10	0.25
		Expenses			0.50		0.60	0.50
		Contingency			0.28		0.40	0.28
		Subtotal	1.50	a)	3.08	n.a.	4.30	3.08
04.2100	Characterisation of radioactive materials	Labour costs		10.18	0.73		1.20	0.83
		Capital		1.07	0.09		0.60	0.10
		Expenses		3.51	0.15		0.50	0.17
		Contingency			0.10		0.30	0.11
		Subtotal	n.a.	14.76	1.07	n.a.	2.60	1.21

(cont.)

Table 4-4. Costs of dismantling activities (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
04.2200	Decontamination for recycling and reuse	Labour costs		0.40	4.31		1.00	4.45
		Capital		1.73	0.63		1.50	0.65
		Expenses		2.40	2.02		2.00	2.03
		Contingency			0.70		0.60	0.71
		Subtotal	n.a.	4.53	7.66	0.00	5.10	7.84
04.2300	Personel training	Labour costs		0.00	0.77		0.00	0.82
		Capital		0.00	0.09		0.00	0.10
		Expenses		1.51	0.15		0.30	0.16
		Contingency			0.10		0.10	0.11
		Subtotal	n.a.	1.51	1.11	n.a.	0.40	1.19
04.2400	Asset recovery: Sale/ transfer of metal or materials, and salvaged equipment or components for recycling or reuse	Labour costs		1.11				
		Capital		0.09				
		Expenses		-8.44				
		Contingency						
		Subtotal	n.a.	-7.24	n.a.	0.00	-5.43	n.a.
Total:			28.00	197.02	53.42	93.00	100.07	59.10

a) Included into 2.0100
b) Included into 4.1800

Table 4-5. Waste processing, storage and disposal costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
05.0100	Waste processing, storage and disposal safety analysis	Labour costs		1.11	0.43			0.43
		Capital		0.00	0.05			0.05
		Expenses		8.09	0.09			0.09
		Contingency			0.06			0.06
		Subtotal	5.60	9.20	0.63	n.a.	1.00	0.63
05.0200	Waste -transport feasibility studies	Labour costs			0.22			0.22
		Capital			0.03			0.03
		Expenses			0.05			0.05
		Contingency			0.03			0.03
		Subtotal	n.a.	0.00	0.33	n.a.	0.20	0.33
05.0300	Special permits, packaging and transport requirements	Labour costs			0.33			0.33
		Capital			0.04			0.04
		Expenses			0.07			0.07
		Contingency			0.04			0.04
		Subtotal	n.a.	0.00	0.48	n.a.	0.80	0.48
05.0400	Processing of system fluids (water, oils, etc.) from facility operations	Labour costs		1.16				
		Capital		2.04				
		Expenses		1.02				
		Contingency						
		Subtotal	1.60	4.22	n.r.	n.a.	1.60	n.r.
05.0500	Processing of special system fluids (D2O, sodium, etc.) from facility operations	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
05.0600	Processing of waste from decontamination during facility operations	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	a)	n.r.	n.a.	n.r.	n.r.
05.0700	Processing of combustible material from facility operations	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	0.10	a)	n.r.	n.a.	1.20	n.r.

(cont.)

Table 4-5. Waste processing, storage and disposal costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
05.0800	Processing of spent resins from facility operation	Labour costs		8.00				
		Capital		2.93				
		Expenses		12.22				
		Contingency						
		Subtotal	n.a.	23.15	n.r.	n.a.	n.r.	n.r.
05.0900	Processing of other nuclear and hazardous materials from facility operation	Labour costs		7.55				
		Capital		2.89				
		Expenses		12.09				
		Contingency						
		Subtotal	0.50	22.53	n.r.	n.a.	3.20	n.r.
05.1000	Storage of waste from facility operations	Labour costs		78.79				
		Capital		6.44				
		Expenses		177.05				
		Contingency						
		Subtotal	10.70	262.28	n.r.	n.r.	n.r.	n.r.
05.1100	Disposal of waste from facility operations	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	1.50	11.38	n.r.	n.a.	n.r.	n.r.
05.1200	Processing of decommissioning waste	Labour costs			7.35			8.27
		Capital			10.62			9.79
		Expenses			12.51			14.04
		Contingency			3.05			3.21
		Subtotal	18.20	50.84	33.53	n.a.	43.00	35.31
05.1300	Packaging of decommissioning waste	Labour costs			3.95			4.38
		Capital			1.08			1.18
		Expenses			2.86			3.13
		Contingency			0.79			0.87
		Subtotal	3.50	b)	8.68	n.a.	12.00	9.56
05.1400	Transport of decommissioning waste	Labour costs		5.56	1.14			1.25
		Capital		0.93	0.25			0.27
		Expenses		0.40	1.32			1.46
		Contingency			0.27			0.30
		Subtotal	n.a.	6.89	2.98	n.a.	8.00	3.28

(cont.)

Table 4-5. Waste processing, storage and disposal costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
05.1500	Storage of decommissioning waste	Labour costs			0.41			0.41
		Capital			4.93			4.93
		Expenses			0.08			0.08
		Contingency			0.54			0.54
		Subtotal	n.r.	c)	5.96	n.r.	5.60	5.96
05.1600	Disposal of decommissioning waste	Labour costs		3.87	2.73			2.97
		Capital		0.36	4.49			4.77
		Expenses		103.37	42.17			44.78
		Contingency			4.94			5.25
		Subtotal	11.60	107.60	54.33	n.a.	185.50	57.77
Total:			53.30	498.09	106.92	42.70	262.10	113.32

a) Included into 02.0100
b) Included imto 05.1600
c) Included into 05.1000

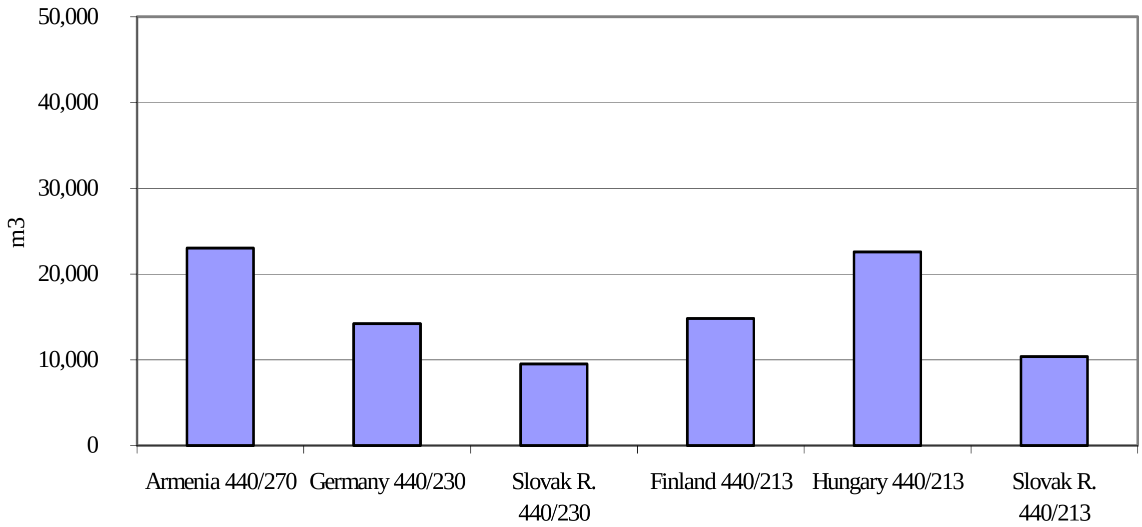

Figure 4-1. Estimated volume of the compacted decommissioning L/ILW (ID).

No significant differences prevail between processing, packaging and transport costs of wastes produced during dismantling activities. Differences are significant, however, in the sub-item "Disposal of decommissioning waste (05.1600)", for the following basic reasons:

(a) In some countries the waste disposal problem has been solved and proper waste disposal capacity is available. In these countries, operators only have to pay a fee for disposal of their wastes.

(b) In countries, however, where no waste repositories are available, cost item 05.1600 will have to include all costs relating to survey, implementation, operation and closure of a dedicated waste disposal facility.

Another reason for the significant differences could be that some of the countries that have no disposal facilities assessed their disposal costs based on specific data from foreign facilities that were taken from technical references, mostly published by the OECD, e.g., [26]. Such specific data may show significant differences and are sometimes much higher than the real costs.

The very high cost figure for Germany is mainly due to the scope included, i.e., construction and operation of the interim storage, processing of operational waste and waste disposal costs.

4.2.6. Site security, surveillance and maintenance costs

An overview of these costs is shown in Table 4-6. They may vary between about 2 and 7 % of the total decommissioning costs.

Table 4-6. Site security, surveillance and maintenance costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
06.0100	Site security and surveillance	Labour costs			4.06		3.60	4.06
		Capital			0.49		0.50	0.49
		Expenses			0.84		0.30	0.84
		Contingency			0.54		0.40	0.54
		Subtotal	2.32	53.68	5.93	n.a.	4.80	5.93
06.0200	Inspection and maintenance of buildings and system in operation	Labour costs			4.06		3.60	4.06
		Capital			0.49		0.30	0.49
		Expenses			0.83		1.80	0.83
		Contingency			0.54		0.40	0.54
		Subtotal	n.a.	a)	5.92	n.a.	6.10	5.92
06.0300	Site upkeep	Labour costs			2.44		0.30	2.44
		Capital			0.29		0.10	0.29
		Expenses			0.49		0.60	0.49
		Contingency			0.32		0.10	0.32
		Subtotal	n.a.	a)	3.54	n.a.	1.10	3.54
06.0400	Energy and water	Labour costs			3.25		0.00	3.25
		Capital			0.39		0.00	0.39
		Expenses			0.65		2.60	0.65
		Contingency			0.43		0.30	0.43
		Subtotal	9.70	a)	4.72	n.a.	2.90	4.72
06.0500	Periodic radiation and environmental survey	Labour costs			1.63		0.50	1.63
		Capital			0.20		0.10	0.20
		Expenses			0.33		0.20	0.33
		Contingency			0.21		0.10	0.21
		Subtotal	2.70	a)	2.37	n.a.	0.90	2.37
Total:			14.72	53.68	22.48	8.00	15.80	22.48

a) Included into item 02.0100

4.2.7. Site restoration, cleanup and landscaping costs

Table 4-7 shows only very small differences in the cost assessments referring to the Hungarian and the Slovakian model 213 units. Differences relating to the demolition of models 230 and 213 units may be explained by a different input inventory.

Costs for this item may vary between 0 and 27 % of the total decommissioning costs for this option. Finland provided a “0” cost figure for this item. In this country, inactive buildings or parts of buildings are not considered to be part of the authorisation system. For this reason, no funding is required for the demolition of the structures. It is left to the owner to decide what he wants to do with the inactive buildings and when.

4.2.8. Project management, engineering and site support costs

Costs relating to this item are shown in Table 4-8. For Armenia it includes the costs for Pre-decommissioning actions (cost item 01), Research and development (cost item 09) as well as part of Other costs (cost item 11).

4.2.9. Research and development costs

An overview of the collected Research and development costs is shown in Table 4-9. Finland and Germany do not consider costs for research and development. Germany, however, did include testing of the remote dismantling of the reactor pressure vessel and its internals in a mock-up facility, though not under the item Research and development. In Finland, the reactor pressure vessel and the internals will be removed and disposed of as a single piece. The dismantling activities become rather simple, therefore, and no specific training is required. Other necessary research and development costs in Finland are included in the operational costs, anyway.

In Hungary, there are no incentives to develop purpose-made machinery due to the limited possible applications. Adequate equipment could eventually be purchased or leased.

4.2.10. Fuel and nuclear material costs

Fuel and nuclear material costs are shown in Table 4-10. Slovakia does not include these costs under this cost item. In Finland operational and maintenance costs for the interim spent fuel storage are not included in the decommissioning costs.

The figures for Germany include the costs for defueling and interim storage of removed fuel in CASTOR containers.

4.2.11. Other costs

An overview of Other costs is given in Table 4-11. The figures under this cost group show a high uncertainty as is indicated by the numerous remarks and the presence of many “n.a.” terms. A very high contingency figure considered as an individual item may provide financial assurance versus inherent uncertainties in waste disposal options.

4.3. COSTS FOR SAFE ENCLOSURE

All participating Member States, except Germany, have also selected safe enclosure as a decommissioning option. In this case, Slovakia, Ukraine and partially Hungary provided a complete cost distribution to the level of cost groups, cost items and sub-items.

Table 4-7. Site restoration, cleanup and landscaping costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
07.0100	Demolition or restoration of buildings	Labour costs			44.12		73.80	61.03
		Capital			9.28		3.60	7.87
		Expenses			12.56		3.70	17.65
		Contingency		*	6.60		9.70	8.65
		Subtotal	25.00	14.50	72.56	n.r.	90.80	95.20
07.0200	Final cleanup and landscaping	Labour costs			0.80		0.70	0.80
		Capital			0.14		0.30	0.14
		Expenses			0.59		0.80	0.59
		Contingency			0.15		0.20	0.15
		Subtotal	n.a.	n.r.	1.68	n.r.	2.00	1.68
07.0300	Independent compliance verification with cleanup and/or site-reuse standards	Labour costs			0.54		1.00	0.54
		Capital			0.07		0.00	0.07
		Expenses			0.13		0.20	0.13
		Contingency			0.07		0.10	0.07
		Subtotal	n.a.	n.r.	0.81	n.r.	1.30	0.81
07.0400	Perpetuity funding/ surveillance for limited or restricted release of property	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
Total:			25.00	14.50	75.05	n.r.	94.10	97.69

* Covers only demolition of a small part of the building as required in order to achieve the legal objectives

Table 4-8. Project management, engineering and site support costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
08.0100	Mobilisation and preparatory work	Labour costs			1.05		0.20	1.05
		Capital			0.16		3.30	0.16
		Expenses			0.53		0.10	0.53
		Contingency			0.17		0.40	0.17
		Subtotal	n.a.	a)	1.91	n.a.	4.00	1.91
08.0200	Project management and engineering services	Labour costs		16.80	7.93		8.90	7.93
		Capital		0.13	0.96		0.40	0.96
		Expenses		0.53	1.63		0.10	1.63
		Contingency			1.05		1.10	1.05
		Subtotal	47.20	17.46	11.57	n.a.	10.50	11.57
08.0300	Public relations	Labour costs			0.78		0.50	0.78
		Capital			0.09		0.10	0.09
		Expenses			0.16		0.10	0.16
		Contingency			0.10		0.10	0.10
		Subtotal	n.a.	a)	1.13	n.a.	0.80	1.13
08.0400	Support services	Labour costs			7.37		1.40	7.37
		Capital			1.21		0.10	1.21
		Expenses			2.04		3.20	2.04
		Contingency			1.06		0.60	1.06
		Subtotal	2.00	a)	11.68	n.a.	5.30	11.68
08.0500	Health and safety	Labour costs			5.07		2.60	5.07
		Capital			0.61		0.70	0.61
		Expenses			1.05		0.60	1.05
		Contingency			0.67		0.50	0.67
		Subtotal	n.a.	a)	7.40	n.a.	4.40	7.40
08.0600	Demobilisation	Labour costs			0.22		0.10	0.22
		Capital			0.03		0.00	0.03
		Expenses			0.05		1.20	0.05
		Contingency			0.03		0.10	0.03
		Subtotal	n.a.	a)	0.33	n.a.	1.40	0.33
Total:			49.20	17.46	34.02	6.00	26.40	34.02

a) Included into item 02.0100

Table 4-9. Research and development costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
09.0100	Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment	Labour costs			1.63		0.30	1.63
		Capital			0.75		0.10	0.75
		Expenses			0.46		0.30	0.46
		Contingency			0.28			0.28
		Subtotal	a)	0.00	3.12	n.r.	0.70	3.12
09.0200	Simulation of complicated work on model	Labour costs			1.30		0.10	1.30
		Capital			1.00		1.50	1.00
		Expenses			0.53		0.10	0.53
		Contingency			0.28		0.20	0.28
		Subtotal	a)	b)	3.11	n.r.	1.90	3.11
Total:			a)	0.00	6.23	n.r.	2.60	6.23

a) Included into item 08

b) Included into item 04.1100

Table 4-10. Fuel and nuclear material costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
10.0100	Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage	Labour costs		8.35				
		Capital		1.24				
		Expenses		5.29				
		Contingency						
		Subtotal	n.a.	14.88	n.r.	n.a.	2.44	n.r.
10.0200	Intermediate storage	Labour costs		2.40				
		Capital		37.02				
		Expenses		2.53				
		Contingency						
		Subtotal	34.00	41.95	n.r.	n.a.	n.r.	n.r.
10.0300	Dismantling/disposal of temporary storage facility	Labour costs		0.76				
		Capital		0.27				
		Expenses		0.18				
		Contingency						
		Subtotal	n.a.	1.21	n.r.	n.a.	n.r.	n.r.
10.0400	Preparation for transfer of fuel or nuclear material from intermediate storage to final disposition	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	n.a.	n.r.	n.a.	n.r.	n.r.
10.0500	Dismantling/disposal of intermediate storage facility	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	n.a.	n.r.	n.a.	24.44	n.r.
Total:			34.00	58.04	0.00	11.00	26.88	0.00

a) Not included

Table 4-11. Other costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
11.0100	Owner costs	Labour costs			0.52			0.52
		Capital			1.28			1.28
		Expenses			0.10			0.10
		Contingency			0.19			0.19
		Subtotal	a)	0.00	2.09	0.00	0.00	2.09
11.0200	General, overall (not specific) consulting costs	Labour costs			0.11			0.11
		Capital			0.01			0.01
		Expenses			0.03		0.50	0.03
		Contingency			0.01		0.10	0.01
		Subtotal	a)	0.00	0.16	0.00	0.60	0.16
11.0300	General, overall (not specific) regulatory fees, inspections, certifications, reviews, etc.	Labour costs			0.11			0.11
		Capital			0.01			0.01
		Expenses			0.03		2.00	0.03
		Contingency			0.01		0.20	0.01
		Subtotal	0.20	n.a.	0.16	0.00	2.20	0.16
11.0400	Taxes	Labour costs			0.00			0.00
		Capital			0.14			0.14
		Expenses			1.35			1.35
		Contingency			0.15			0.15
		Subtotal	n.a.	n.a.	1.64	n.a.	n.a.	1.64
11.0500	Insurances	Labour costs			0.00			0.00
		Capital			0.14			0.14
		Expenses			1.35		2.00	1.35
		Contingency			0.15		0.20	0.15
		Subtotal	a)	0.00	1.64	n.a.	2.20	1.64
11.0600	Overheads and general administration	Labour costs			1.63			1.63
		Capital			0.20			0.20
		Expenses			0.33		1.50	0.33
		Contingency			0.21		0.20	0.21
		Subtotal	a)	n.a.	2.37	0.00	1.70	2.37
11.0700	Contingency	Labour costs			0.00			0.00
		Capital			1.49			1.49
		Expenses			1.35			1.35
		Contingency			0.28			0.28
		Subtotal	a)	0.00	3.12	n.a.	20.50	3.12

(cont.)

Table 4-11. Other costs (ID)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998					
			Armenia	Germany	Slovak R.	Finland	Hungary	Slovak R.
			440/270	440/230	440/230	440/213	440/213	440/213
11.0800	Interest on borrowed money	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	0.00	n.a.	0.00	0.00	n.a.
11.0900	Asset recovery: Resale/ transfer of general equipment and material	Labour costs						
		Capital						
		Expenses						
		Contingency						
		Subtotal	n.a.	n.a.	n.a.	0.00	n.a.	n.a.
Total:			0.20	n.a.	11.18	11.50	27.20	11.18

a) Included into 08.0200

In Germany, shortly after shutdown, a detailed comparison between the two options was performed. This comparison showed that for the Greifswald units immediate decommissioning offers advantages in the area of costs, dose commitments and produced radioactive waste volumes [26].

4.3.1. Costs of pre-decommissioning actions

Table 4-12 shows the costs for the pre-decommissioning activities in this option. In general, there is no good agreement between the related cost assessment.

As in the immediate decommissioning option, Armenia included these costs under project management activities. For the Czech Republic, the reported costs are lower than for other countries due to financing from other sources as well.

The costs in Bulgaria and in the Russian Federation are significantly higher than in other countries. The larger size of the Kozloduy site may be a reason. In Bulgaria, “Radiological surveys for planning and licensing (01.0300)” are considered to be part of “Decommissioning planning (01.0100)”.

4.3.2. Costs of facility shutdown activities

Facility shutdown costs are shown in Table 4–13. In the safe enclosure option, the shutdown period is not always used to perform a decontamination of the reactor vessel and primary loop prior to disassembly as was the case in the immediate decommissioning option. In some countries only decontamination of components after dismantling, and decontamination of civil works is considered.

4.3.3. Costs of procurement of general equipment and material

The results for this cost group are indicated in Table 4-14. The costs may significantly change if the organisation that is responsible for the decommissioning activities also operates other nuclear power plants (on site), and has a pool of hoisting machinery that could be used in the decommissioning work, avoiding the need for procurement or leasing of this type of equipment. In some decommissioning projects this statement may also refer to, i.e., very specific concrete breakers or other processing equipment.

4.3.4. Costs of dismantling activities

An overview of the costs for the dismantling activities is shown in Table 4-15. The costs given under the sub-item “Drainage of spent fuel pool and decontamination of linings (04.0200)” are similar to the values given in the option immediate decommissioning. Though the costs show no big differences, the applied technology can vary. A good cost estimate is recommended for the items 04.0100 to 04.0700 as in case of the delayed option, these activities for one unit are accomplished in a time interval of 3 to 5 years following shutdown.

In case of safe enclosure, it might be necessary to replace active elements of systems remaining in operation, e.g., ventilators. Detailed construction designs for modifications in view of long term safe enclosure have nowhere been completed, however. In some countries decisions on a possible active or passive mode of long term storage were not taken. As a result, costs can only be rough estimates.

None of the countries that intend to select the safe enclosure option seem to include dismantling and transfer of contaminated equipment and material to containment structure for long term storage in their activities for preparing the safe enclosure period. Most of the

Table 4-12. Costs of pre-decommissioning actions (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
01.0100	Decommissioning planning	Labour costs		7.65		3.63			3.40		3.63	0.30
		Capital		0.81		0.44			0.00		0.44	0.80
		Expenses		0.81		0.73			0.70		0.73	0.50
		Contingency		0.00		0.48			0.50		0.48	0.20
		Subtotal	n.a.	9.27	n.a.	5.28	n.a.	n.a.	4.60	n.a.	5.28	1.80
01.0200	Authorisation	Labour costs		6.30		0.67			1.90		0.67	0.10
		Capital		0.00		0.08			0.00		0.08	0.00
		Expenses		2.70		0.13			0.40		0.13	0.20
		Contingency		0.00		0.09			0.30		0.09	0.10
		Subtotal	n.a.	9.00	n.a.	0.97	n.a.	n.a.	2.60	n.a.	0.97	0.40
01.0300	Radiological surveys for planning and licensing	Labour costs				0.49			0.60		0.49	0.10
		Capital				0.06			0.20		0.06	0.20
		Expenses				0.10			0.50		0.10	0.20
		Contingency				0.06			0.20		0.06	0.00
		Subtotal	n.a.	b)	n.a.	0.71	n.r.	n.a.	1.50	n.a.	0.71	0.50
01.0400	Hazardous-material surveys and analysis	Labour costs		0.15		0.22			0.30		0.22	0.10
		Capital		0.03		0.03			0.10		0.03	0.10
		Expenses		0.22		0.04			0.10		0.04	0.10
		Contingency				0.03			0.00		0.03	0.00
		Subtotal	n.a.	0.40	n.a.	0.32	n.r.	0.00	0.50	n.a.	0.32	0.30
01.0500	Prime contracting selection	Labour costs				0.09					0.09	0.10
		Capital				0.03					0.03	0.00
		Expenses				0.02					0.02	0.30
		Contingency				0.01					0.01	0.00
		Subtotal	n.a.	n.a.	n.a.	0.15	n.r.	n.a.	c)	n.a.	0.15	0.40
Total:			a)	18.67	20.60	7.43	1.50	7.40	9.20	20.60	7.43	3.40

a) Included into item 08.0200
b) Included into item 01.0100
c) The cost is less than 0.1 MUSD.

Table 4-13. Costs of facility shutdown activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
02.0100	Plant shutdown and inspection	Labour costs		18.72		0.48			43.10		0.48	0.20
		Capital		1.80		0.07			1.00		0.07	0.00
		Expenses				0.24			2.70		0.24	0.20
		Contingency				0.08			5.60		0.08	0.00
		Subtotal	n.a.	20.52	n.a.	0.87	n.a.	n.a.	52.40	n.a.	0.87	0.40
02.0200	Removal of fuel and/or nuclear fuel materials	Labour costs				0.22					0.22	0.20
		Capital				0.03					0.03	0.00
		Expenses				0.04					0.04	0.20
		Contingency				0.03					0.03	0.00
		Subtotal	n.a.	a)	n.a.	0.32	n.a.	n.a.	a)	n.a.	0.32	0.40
02.0300	Drainage and drying or blow down of all systems not in operation	Labour costs				0.13					0.13	0.20
		Capital				0.02					0.02	0.10
		Expenses				0.03					0.03	0.40
		Contingency				0.02					0.02	0.10
		Subtotal	n.a.	a)	n.a.	0.20	n.a.	n.a.	a)	n.a.	0.20	0.80
02.0400	Sampling for radiological inventory characterisation after plant shutdown, defueling and drainage and drying or blow down of syst.	Labour costs		0.22		0.46			0.90		0.46	0.10
		Capital		0.36		0.06			0.00		0.06	0.10
		Expenses		1.44		0.15			0.20		0.15	0.30
		Contingency				0.07			0.10		0.07	0.10
		Subtotal	n.a.	2.02	n.a.	0.74	n.a.	n.a.	1.20	n.a.	0.74	0.60
02.0500	Removal of system fluids (water, oils, etc.)	Labour costs				0.13					0.13	0.20
		Capital				0.02					0.02	0.00
		Expenses				0.03					0.03	1.10
		Contingency				0.02					0.02	0.00
		Subtotal	1.10	a)	n.a.	0.20	n.a.	n.a.	a)	n.a.	0.20	1.30
02.0600	Removal of special system fluids (D2O, sodium, etc.)	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
02.0700	Decontamination of systems for dose reduction	Labour costs		0.45		0.16			0.00		0.16	0.20
		Capital		1.96		0.02			0.00		0.02	0.30
		Expenses		2.14		0.08			0.00		0.08	0.60
		Contingency				0.03			0.00		0.03	0.10
		Subtotal	3.00	4.55	n.a.	0.29	n.a.	0.00	0.00	n.a.	0.29	1.20

(cont.)

Table 4-13. Costs of facility shutdown activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
02.0800	Removal of waste from decontamination	Labour costs				0.04			0.00		0.04	0.10
		Capital				0.01			0.00		0.01	0.00
		Expenses				0.04			0.00		0.04	0.30
		Contingency				0.01			0.00		0.01	0.00
		Subtotal	n.a.	c)	n.a.	0.10	n.a.	n.a.	0.00	n.a.	0.10	0.40
02.0900	Removal of combustible material	Labour costs				0.03					0.03	0.10
		Capital				0.00					0.00	0.00
		Expenses				0.01					0.01	0.00
		Contingency				0.00					0.00	0.10
		Subtotal	n.a.	a)	n.a.	0.04	n.r.	0.00	a)	n.a.	0.04	0.20
02.1000	Removal of spent resins	Labour costs				0.02					0.02	0.10
		Capital				0.00					0.00	0.20
		Expenses				0.00					0.00	0.10
		Contingency				0.00					0.00	0.10
		Subtotal	n.a.	a)	n.a.	0.02	n.r.	n.a.	a)	n.a.	0.02	0.50
02.1100	Removal of other waste from facility operation	Labour costs				0.03					0.03	0.10
		Capital				0.00					0.00	0.00
		Expenses				0.01					0.01	0.10
		Contingency				0.00					0.00	0.10
		Subtotal	n.a.	a)	n.a.	0.04	n.r.	0.00	n.r.	n.a.	0.04	0.30
02.1200	Isolation of power equipment	Labour costs				0.16					0.16	0.10
		Capital				0.02					0.02	0.40
		Expenses				0.03					0.03	0.20
		Contingency				0.02					0.02	0.10
		Subtotal	n.a.	n.a.	n.a.	0.23	b)	n.a.	a)	n.a.	0.23	0.80
02.1300	Asset recovery: Resale of facility equipment and components as well as surplus inventory to other licensed ……..	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.a.	n.a.	n.a.	0.00	0.00	0.00	n.a.	n.a.	0.00
Total:			4.10	27.09	b)	3.05	2.70	24.80	53.60	b)	3.05	6.90

a) Included into 02.0100

b) Included into the total cost of decommissioning, not specified for given area

c) Included into 05.1200

Table 4-14. Costs of procurement of general equipment and material (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
03.0100	General site dismantling equipment	Labour costs				0.05			0.00		0.05	0.00
		Capital		0.18		1.11			6.10		1.11	3.50
		Expenses				0.01			0.00		0.01	0.00
		Contingency				0.12			0.70		0.12	0.30
		Subtotal	3.50	0.18	n.a.	1.29	n.a.	n.a.	6.80	n.a.	1.29	3.80
03.0200	General equipment for personel/tooling decontamination	Labour costs				0.03			0.00		0.03	0.00
		Capital		0.45		0.14			1.50		0.14	2.00
		Expenses				0.00			0.00		0.00	0.00
		Contingency				0.02			0.20		0.02	0.20
		Subtotal	0.50	0.45	n.a.	0.19	n.a.	n.a.	1.70	n.a.	0.19	2.20
03.0300	General radiation protection and health physics equipment	Labour costs				0.44			0.00		0.44	0.00
		Capital		0.99		4.66			0.80		4.66	0.50
		Expenses				0.09			0.00		0.09	0.00
		Contingency				0.52			0.10		0.52	0.00
		Subtotal	n.a.	0.99	n.a.	5.71	n.a.	n.a.	0.90	n.a.	5.71	0.50
03.0400	General security and maintenance equipment for long term storage	Labour costs				0.11			0.00		0.11	0.00
		Capital		3.42		0.12			0.50		0.12	0.30
		Expenses				0.29			0.00		0.29	0.00
		Contingency				0.05			0.10		0.05	0.00
		Subtotal	n.a.	3.42	n.a.	0.57	n.a.	n.a.	0.60	n.a.	0.57	0.30
Total:			4.00	5.04	n.a.	7.76	3.40	8.20	10.00	n.a.	7.76	6.80

Comment: In case of Bulgaria these costs are solely contined to the Final Shutdown,
Preparation of Safe Enclosure and partly for Safe Enclosure Stages

Table 4-15. Costs of dismantling activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
04.0100	Decontamination of areas and equipment in buildings to facilitate dismantling	Labour costs				1.41			0.00		1.41	0.30
		Capital				0.98			0.00		0.98	0.40
		Expenses				0.28			0.00		0.28	2.00
		Contingency				0.27			0.00		0.27	0.20
		Subtotal	n.a.	n.a.	n.a.	2.94	n.a.	n.a.	0.00	n.a.	2.94	2.90
04.0200	Drainage of spent-fuel pool and decontamination of linings	Labour costs				0.11			0.00		0.11	0.10
		Capital				0.07			0.00		0.07	0.00
		Expenses				0.03			0.10		0.03	0.20
		Contingency				0.02			0.00		0.02	0.00
		Subtotal	n.a.	a)	n.a.	0.23	n.a.	n.a.	0.10	n.a.	0.23	0.30
04.0300	Preparation for dormancy	Labour costs		0.36		0.41					0.41	0.10
		Capital		0.36		0.10					0.10	0.00
		Expenses		0.67		0.08					0.08	0.10
		Contingency				0.06					0.06	0.00
		Subtotal	n.a.	1.39	n.a.	0.65	n.a.	n.a.	n.r.	n.a.	0.65	0.20
04.0400	Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage	Labour costs				0.33					0.33	0.30
		Capital				0.07					0.07	0.50
		Expenses				0.07					0.07	0.20
		Contingency				0.05					0.05	0.20
		Subtotal	n.a.	n.r.	n.a.	0.52	0.00	n.a.	n.r.	n.a.	0.52	1.20
04.0500	Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy	Labour costs		0.14		0.08					0.08	0.10
		Capital		0.18		0.01					0.01	0.10
		Expenses		0.90		0.02					0.02	0.20
		Contingency				0.01					0.01	0.00
		Subtotal	n.a.	1.22	n.a.	0.12	c)	n.a.	n.r.	n.a.	0.12	0.40
04.0600	Site reconfiguration, isolating and securing structures	Labour costs		1.98		1.03			0.00		1.03	0.20
		Capital				0.13			0.00		0.13	0.30
		Expenses		0.72		0.26			0.00		0.26	0.40
		Contingency				0.14			0.00		0.14	0.00
		Subtotal	n.a.	2.70	n.a.	1.56	n.a.	n.a.	0.00	n.a.	1.56	0.90
04.0700	Facility (controled area) hardening, isolation or entombment	Labour costs		0.90		0.16			0.00		0.16	0.20
		Capital		4.05		0.02			0.00		0.02	0.80
		Expenses				0.04			0.00		0.04	0.60
		Contingency		1.08		0.02			0.00		0.02	0.20
		Subtotal	n.a.	6.03	n.a.	0.24	n.a.	n.a.	0.00	n.a.	0.24	1.80

(cont)

Table 4-15. Costs of dismantling activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
04.0800	Radiological inventory characterisation for decommissioning and decontamination	Labour costs		0.09		0.17			1.50		0.17	0.10
		Capital		0.21		0.19			0.10		0.19	0.10
		Expenses		0.77		1.70			0.30		1.70	0.40
		Contingency				0.21			0.20		0.21	0.10
		Subtotal	n.a.	1.07	n.a.	2.27	n.a.	n.a.	2.10	n.a.	2.27	0.70
04.0900	Preparation of temporary waste storage area	Labour costs				0.08			0.10		0.08	0.20
		Capital				0.07			0.10		0.07	1.30
		Expenses				0.03			0.10		0.03	0.40
		Contingency				0.02			0.00		0.02	0.20
		Subtotal	n.a.	n.r.	n.a.	0.20	n.r.	n.a.	0.30	n.a.	0.20	2.10
04.1000	Removal of fuel-handling equipment	Labour costs				0.14					0.14	0.10
		Capital				0.10					0.10	0.40
		Expenses				0.03					0.03	0.30
		Contingency				0.03					0.03	0.10
		Subtotal	n.a.	b)	n.a.	0.30	n.a.	n.a.	0.05	n.a.	0.30	0.90
04.1100	Design, procurement, and testing of special tooling/ equipment for remote dismantling	Labour costs				0.54			0.00		0.54	0.20
		Capital				2.18			5.60		2.18	0.20
		Expenses				0.11			0.10		0.11	0.30
		Contingency				0.28			0.70		0.28	0.10
		Subtotal	n.a.	b)	n.a.	3.11	n.a.	n.a.	6.45	n.a.	3.11	0.80
04.1200	Dismantling operations on reactor vessel internals	Labour costs				1.74			2.00		1.74	0.50
		Capital				0.63			0.40		0.63	3.20
		Expenses				0.35			1.00		0.35	0.40
		Contingency				0.27			0.40		0.27	0.10
		Subtotal	0.10	b)	n.a.	2.99	n.a.	n.a.	3.80	n.a.	2.99	4.20
04.1300	Removal of primary and auxiliary systems	Labour costs		54.00		11.15			26.90		14.48	0.20
		Capital		23.50		2.69			6.80		3.49	0.40
		Expenses		16.50		2.30			6.80		2.98	0.60
		Contingency				1.61			6.50		2.10	0.10
		Subtotal	24.00	94.00	n.a.	17.75	n.a.	n.a.	47.00	n.a.	23.05	1.30
04.1400	Removal of biological/ thermal shield	Labour costs				0.09			0.30		0.09	0.20
		Capital				0.01			0.20		0.01	0.40
		Expenses				0.02			0.50		0.02	0.60
		Contingency				0.01			0.10		0.01	0.20
		Subtotal	0.20	b)	n.a.	0.13	n.a.	n.a.	1.10	n.a.	0.13	1.40

(cont)

Table 4-15. Costs of dismantling activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
04.1500	Removal of other material/ equipment from containment structure and all other facilities, or removal of entire contaminated facilities	Labour costs				4.25			3.60		4.27	0.30
		Capital				0.51			0.40		0.52	0.50
		Expenses				0.89			0.30		0.90	0.30
		Contingency				0.57			0.50		0.57	0.20
		Subtotal	0.30	b)	n.a.	6.22	c)	n.a.	4.80	n.a.	6.26	1.30
04.1600	Removal and disposal of asbestos	Labour costs				0.11			1.00		0.11	0.10
		Capital				0.01			1.50		0.01	0.10
		Expenses				0.02			1.00		0.02	0.00
		Contingency				0.01			0.40		0.01	0.00
		Subtotal	n.a.	n.r.	n.a.	0.15	n.r.	0.00	3.90	n.a.	0.15	0.20
04.1700	Removal of pool linings	Labour costs				0.18			0.40		0.18	0.20
		Capital				0.04			0.20		0.04	0.00
		Expenses				0.04			0.30		0.04	0.40
		Contingency				0.03			0.10		0.03	0.00
		Subtotal	n.a.	b)	n.a.	0.29	n.a.	n.a.	1.00	n.a.	0.29	0.60
04.1800	Building decontamination	Labour costs		7.00		1.25			1.80		1.25	0.20
		Capital		5.20		0.15			0.60		0.15	0.40
		Expenses		3.80		0.28			1.10		0.28	1.60
		Contingency				0.17			0.40		0.17	0.20
		Subtotal	2.00	16.00	n.a.	1.85	n.a.	n.a.	3.90	n.a.	1.85	2.40
04.1900	Environmental cleanup	Labour costs				0.35			2.50		0.35	0.30
		Capital				0.04			0.60		0.04	1.00
		Expenses				0.07			0.50		0.07	0.40
		Contingency				0.05			0.40		0.05	0.20
		Subtotal	n.a.	1.20	n.a.	0.51	n.a.	n.a.	4.00	n.a.	0.51	1.90
04.2000	Final radioactivity survey	Labour costs		0.32		2.05			1.20		2.05	0.10
		Capital		0.60		0.25			2.10		0.25	0.10
		Expenses		1.20		0.50			0.60		0.50	0.20
		Contingency				0.28			0.40		0.28	0.00
		Subtotal	1.50	2.12	n.a.	3.08	n.a.	n.a.	4.30	n.a.	3.08	0.40
04.2100	Characterisation of radioactive materials	Labour costs		10.00		0.68			1.20		0.79	0.20
		Capital		1.50		0.08			0.60		0.09	0.00
		Expenses		3.50		0.14			0.50		0.16	0.40
		Contingency				0.09			0.30		0.10	0.00
		Subtotal	n.a.	15.00	n.a.	0.99	n.a.	n.a.	2.60	n.a.	1.14	0.60

(cont)

Table 4-15. Costs of dismantling activities (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
04.2200	Decontamination for recycling and reuse	Labour costs		0.80		4.62			0.50		4.79	0.30
		Capital		3.20		0.68			0.80		0.70	0.20
		Expenses		4.50		2.16			1.00		2.19	0.60
		Contingency				0.75			0.30		0.77	0.10
		Subtotal	n.a.	8.50	n.a.	8.21	n.a.	0.00	2.60	n.a.	8.45	1.20
04.2300	Personel training	Labour costs				0.78			0.00		0.83	0.10
		Capital				0.09			0.00		0.10	0.00
		Expenses				0.16			0.30		0.17	0.10
		Contingency				0.10			0.10		0.11	0.00
		Subtotal	n.a.	2.70	n.a.	1.13	n.a.	n.a.	0.40	n.a.	1.21	0.20
04.2400	Asset recovery: Sale/ transfer of metal or materials, and salvaged equipment or components for recycling or reuse	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.a.	n.a.	n.a.	n.a.	0.00	-5.43	n.a.	n.a.	0.00
Total:			28.10	151.93	165.20	55.44	14.90	83.00	82.97	148.70	61.25	27.90

a) Included into item 02.0100
b) Included into item 04.13000
c) Included into the total cost of decommissioning, not specified for given area

countries prefer to leave all activated elements at their original place. Only Russia considers that some compartments of the units may be utilised for regional radioactive waste storage.

The safe enclosure option might require higher training costs as a quite new generation will be involved in the practical decommissioning activities. A higher financial reserve should also be ensured for the casual amendments of law and regulations during the expected enclosure period.

4.3.5. Waste processing, storage and disposal costs

Estimated volumes of conditioned L/ILW decommissioning waste are shown in Figure 4-2. Related cost figures are shown in Table 4-16. The considerations given in paragraph 4.2.5 are also valid for this option. Reasons for the significant differences that were evaluated had been found in the costs for final disposal of wastes.

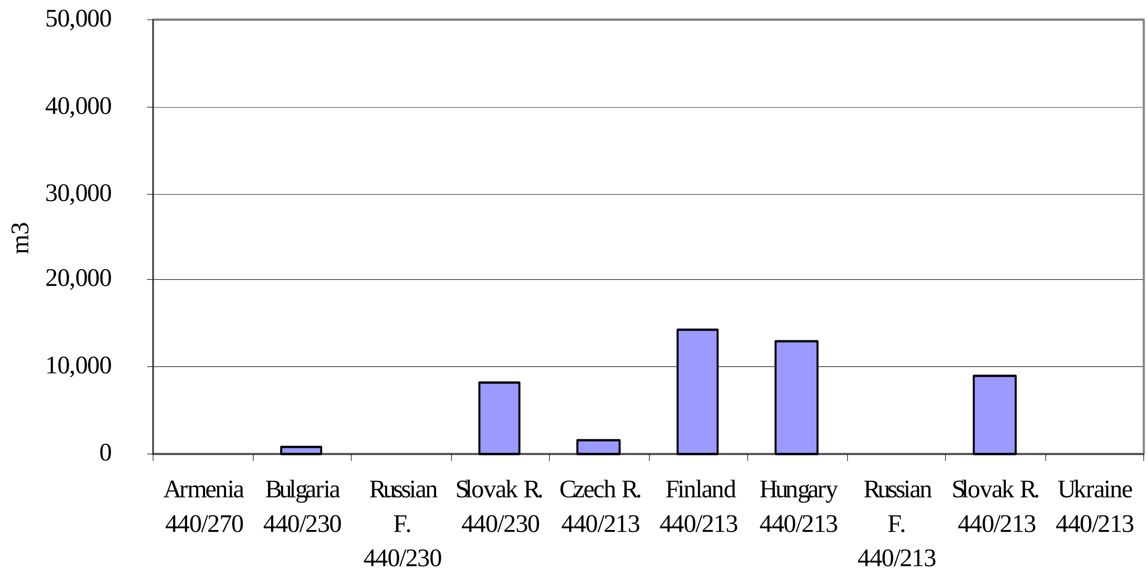

Figure 4-2. Estimated volume of the compacted decommissioning L/ILW (SE).

4.3.6. Site security, surveillance and maintenance costs

In the safe enclosure option, the decay period is a decisive factor relating to the total costs. Another factor is the extent and the type of the safe enclosure. For WWER-440 NPPs, the duration of the safe enclosure period may vary from 20 to 70 years. Most of the countries have chosen for the so-called passive enclosure system with a required staff of 20-40 persons, significantly reducing the related costs. The basic tasks of the personnel are:

a) Operation and surveillance of the security system;

b) Operation and maintenance of buildings remaining in operation;

c) Site upkeep;

d) Performing radiological and environmental surveys if required.

Table 4-16. Waste processing, storage and disposal costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
05.0100	Waste processing, storage and disposal safety analysis	Labour costs				0.43					0.43	
		Capital				0.05					0.05	
		Expenses				0.09					0.09	
		Contingency				0.06					0.06	
		Subtotal	5.56	n.r.	n.a.	0.63	n.a.	n.a.	1.00	n.a.	0.63	n.r.
05.0200	Waste -transport feasibility studies	Labour costs				0.22					0.22	
		Capital				0.03					0.03	
		Expenses				0.05					0.05	
		Contingency				0.03					0.03	
		Subtotal	n.a.	n.r.	n.a.	0.33	n.a.	n.a.	0.20	n.a.	0.33	n.r.
05.0300	Special permits, packaging and transport requirements	Labour costs				0.33					0.33	
		Capital				0.04					0.04	
		Expenses				0.07					0.07	
		Contingency				0.04					0.04	
		Subtotal	n.a.	n.r.	n.a.	0.48	n.a.	n.a.	0.80	n.a.	0.48	n.r.
05.0400	Processing of system fluids (water, oils, etc.) from facility operations	Labour costs										0.80
		Capital										8.00
		Expenses										7.20
		Contingency										0.30
		Subtotal	1.57	n.r.	b)	n.r.	n.r.	n.a.	1.60	b)	n.r.	16.30
05.0500	Processing of special system fluids (D2O, sodium, etc.) from facility operations	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
05.0600	Processing of waste from decontamination during facility operations	Labour costs										0.50
		Capital										19.20
		Expenses										20.60
		Contingency										0.20
		Subtotal	n.a.	n.r.	b)	n.r.	n.r.	n.a.	n.r.	b)	n.r.	40.50
05.0700	Processing of combustible material from facility operations	Labour costs										0.10
		Capital										0.00
		Expenses										0.10
		Contingency										0.00
		Subtotal	0.09	n.r.	b)	n.r.	n.r.	n.a.	1.20	b)	n.r.	0.20

(cont)

Table 4-16. Waste processing, storage and disposal costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
05.0800	Processing of spent resins from facility operation	Labour costs										0.10
		Capital										0.80
		Expenses										0.60
		Contingency										0.10
		Subtotal	n.a.	n.r.	b)	n.r.	n.r.	n.a.	n.r.	b)	n.r.	1.60
05.0900	Processing of other nuclear and hazardous materials from facility operation	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	0.71	n.r.	b)	n.r.	n.r.	n.r.	3.20	b)	n.r.	n.r.
05.1000	Storage of waste from facility operations	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	10.70	n.r.	n.a.	n.r.	n.r.	n.a.	n.r.	n.a.	n.r.	n.r.
05.1100	Disposal of waste from facility operations	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	1.50	n.r.	n.a.	n.r.	c)	n.a.	n.r.	n.a.	n.r.	n.r.
05.1200	Processing of decommissioning waste	Labour costs		2.88		7.35					8.25	1.30
		Capital				10.20					11.27	25.00
		Expenses		2.34		11.64					13.18	37.40
		Contingency				2.92					3.27	0.50
		Subtotal	12.40	5.22	b)	32.11	n.a.	n.a.	15.00	b)	35.97	64.20
05.1300	Packaging of decommissioning waste	Labour costs				3.90					4.33	0.00
		Capital				1.01					1.12	5.00
		Expenses				2.66					2.94	0.00
		Contingency				0.76					0.84	0.00
		Subtotal	3.47	a)	b)	8.33	n.a.	n.a.	4.00	b)	9.23	5.00
05.1400	Transport of decommissioning waste	Labour costs				1.07					1.19	0.60
		Capital				0.23					0.26	4.00
		Expenses				1.26					1.40	3.90
		Contingency				0.26					0.29	0.20
		Subtotal	n.a.	a)	n.a.	2.82	n.a.	n.a.	3.00	n.a.	3.14	8.70

(cont.)

Table 4-16. Waste processing, storage and disposal costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
05.1500	Storage of decommissioning waste	Labour costs		2.25		0.41					0.41	
		Capital		0.45		4.93					4.93	
		Expenses		0.27		0.08					0.08	
		Contingency				0.54					0.54	
		Subtotal	n.r.	2.97	n.a.	5.96	n.r.	n.a.	0.00	n.a.	5.96	n.a.
05.1600	Disposal of decommissioning waste	Labour costs				2.33					2.57	
		Capital				2.92					3.04	
		Expenses				26.90					27.85	
		Contingency				3.22					3.35	
		Subtotal	11.59	2.52	n.a.	35.37	c)	n.a.	54.10	n.a.	36.81	n.a.
Total:			47.59	10.71	13.60	86.03	17.30	40.00	84.10	13.60	92.55	136.50

a) Included into item 05.1200
b) Included into item 04
c) Paid from the nuclear account
d) In case of Bulgaria the costs of the cost items 3,5,8, and 11 are solely contined to the Final Shutdown, Preparation of Safe Enclosure and partly for Safe Enclosure Stages

Costs may be reduced if the periodic radiological and environmental surveys are outsourced.

A comparison of the collected costs is shown in Table 4-17. The cost figures are proportional to the number of personnel and to the duration of the safe enclosure period, respectively. In some cases the costs may amount up to some 34 % of the total decommissioning costs.

4.3.7. Site restoration, cleanup and landscaping costs

An overview of the collected costs is shown in Table 4-18. As these activities are practically independent of the selected decommissioning option, the cost data are nearly identical to the data for immediate decommissioning. The evaluations given in paragraph 4.2.7 are also valid.

In the safe enclosure option, the same good agreement exists between the cost assessments for the Bulgarian and the Slovakian model 230 NPPs as was found for the Hungarian and Slovakian model 213 NPPs.

4.3.8. Project management, engineering and site support costs

An overview of the collected costs is given in Table 4-19. In Slovakia the calculation is based on an estimate of the staff personnel that may be required to manage and support the decommissioning activities. In a next review of the figures, differences may be expected but they should not be significant.

Similar to the immediate decommissioning option, the Armenian costs include the costs for pre-decommissioning actions (cost item 01), research and development (cost item 09) and part of Other costs (cost item 11).

4.3.9. Research and development costs

Costs relating to Research and development are shown in Table 4-20. It is clear that research and development expenditures for this option are lower than for immediate decommissioning.

4.3.10. Fuel and nuclear material costs

Costs for Fuel and nuclear material are identical in the two decommissioning options.

4.3.11. Other costs

Other costs are presented in Table 4-22. In many countries, the VAT item is uncertain also for this option. According to the data submitted, Ukraine has the highest VAT value, amounting up to 15 % of the total decommissioning costs.

4.4. EVALUATION OF THE COSTS OF THE TWO DECOMMISSIONING OPTIONS

4.4.1. Costs of pre-decommissioning actions

Tables 4-1 and 4-12 indicate that there are no significant differences in the costs of pre-decommissioning actions when comparing the two options immediate decommissioning and safe enclosure. In principle, differences could arise when the time periods up to planned shutdown differ, and available studies should be reviewed on a regular basis. The cost data do not reflect such influencing parameters, as this kind of expenditure is small compared to the impact of the entire preparatory work. In deferred decommissioning it can neither be detected whether increased attention should be paid to preserve the operational documentation and drawings for the next 20 to 70 years.

Table 4-17. Site security, surveillance and maintenance costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
06.0100	Site security and suveillance	Labour costs				3.74			5.80		3.74	2.10
		Capital				0.46			1.00		0.46	0.00
		Expenses				0.86			0.80		0.86	0.20
		Contingency				0.51			0.90		0.51	0.10
		Subtotal	9.88	n.a.	n.a.	5.57	n.a.	n.a.	8.50	n.a.	5.57	2.40
06.0200	Inspection and maintenance of buildings and system in operation	Labour costs				5.36			12.90		5.36	0.20
		Capital				0.68			0.80		0.68	0.50
		Expenses				1.41			6.10		1.41	2.00
		Contingency				0.75			1.20		0.75	0.20
		Subtotal	n.a.	n.a.	n.a.	8.20	n.a.	n.a.	21.00	n.a.	8.20	2.90
06.0300	Site upkeep	Labour costs				2.44			0.90		2.44	0.30
		Capital				0.29			0.30		0.29	1.00
		Expenses				0.49			1.80		0.49	0.40
		Contingency				0.32			0.40		0.32	0.10
		Subtotal	0.91	n.a.	n.a.	3.54	n.a.	n.a.	3.40	n.a.	3.54	1.80
06.0400	Energy and water	Labour costs				3.25			0.00		3.25	0.00
		Capital				0.39			0.00		0.39	0.00
		Expenses				0.65			7.20		0.65	5.50
		Contingency				0.43			0.90		0.43	0.00
		Subtotal	10.21	n.a.	n.a.	4.72	n.a.	n.a.	8.10	n.a.	4.72	5.50
06.0500	Periodic radiation and environmental survey	Labour costs				1.63			2.00		1.63	0.20
		Capital				0.20			0.50		0.20	0.00
		Expenses				0.33			1.50		0.33	0.20
		Contingency				0.21			0.50		0.21	0.00
		Subtotal	3.05	n.a.	n.a.	2.37	n.a.	n.a.	4.50	n.a.	2.37	0.40
Total:			24.05	47.25	a)	24.40	70.30	69.00	45.50	a)	24.40	13.00

a) Included into the total decommissioning cost, but not specified for the given area

Table 4-18. Site restoration, cleanup and landscaping costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
07.0100	Demolition or restoration of buildings	Labour costs				44.12			73.80		61.03	0.70
		Capital				9.28			3.60		7.87	2.20
		Expenses				12.56			3.70		17.65	0.40
		Contingency				6.60			9.70		8.65	0.20
		Subtotal	25.00	n.a.	n.a.	72.56	n.a.	n.r.	90.80	n.a.	95.20	3.50
07.0200	Final cleanup and landscaping	Labour costs				0.80			0.70		0.80	0.40
		Capital				0.14			0.30		0.14	1.50
		Expenses				0.59			0.80		0.59	0.80
		Contingency				0.15			0.20		0.15	0.20
		Subtotal	n.a.	n.a.	n.a.	1.68	n.a.	n.r.	2.00	n.a.	1.68	2.90
07.0300	Independent compliance verification with cleanup and/or site-reuse standards	Labour costs				0.54			1.00		0.54	
		Capital				0.07			0.00		0.07	
		Expenses				0.13			0.20		0.13	
		Contingency				0.07			0.10		0.07	
		Subtotal	n.a.	n.a.	n.a.	0.81	n.a.	n.r.	1.30	n.a.	0.81	0.40
07.0400	Perpetuity funding/ surveillance for limited or restricted release of property	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.a.	n.a.	n.r.	n.r.	n.r.	n.r.	n.a.	n.r.	0.00
Total:			25.00	72.00	38.50	75.05	95.40	n.r.	94.10	34.60	97.69	6.80

Table 4-19. Project management, engineering and site support costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
08.0100	Mobilisation and preparatory work	Labour costs				1.05			0.20		1.05	0.20
		Capital				0.16			3.30		0.16	0.40
		Expenses				0.53			0.10		0.53	0.40
		Contingency				0.17			0.40		0.17	0.10
		Subtotal	n.a.	n.a.	n.a.	1.91	b)	n.a.	4.00	n.a.	1.91	1.10
08.0200	Project management and engineering services	Labour costs		8.75		7.93			8.90		7.93	0.30
		Capital				0.96			0.40		0.96	0.20
		Expenses		1.71		1.63			0.10		1.63	0.80
		Contingency				1.05			1.10		1.05	0.10
		Subtotal	88.41	10.46	n.a.	11.57	b)	n.a.	10.50	n.a.	11.57	1.40
08.0300	Public relations	Labour costs				0.78			0.50		0.78	0.10
		Capital				0.09			0.10		0.09	0.00
		Expenses				0.16			0.10		0.16	0.30
		Contingency				0.10			0.10		0.10	0.00
		Subtotal	n.a.	n.a.	n.a.	1.13	b)	n.a.	0.80	n.a.	1.13	0.40
08.0400	Support services	Labour costs				7.37			1.40		7.37	0.30
		Capital				1.21			0.10		1.21	0.30
		Expenses				2.04			3.20		2.04	0.40
		Contingency				1.06			0.60		1.06	0.10
		Subtotal	2.38	a)	n.a.	11.68	b)	n.a.	5.30	n.a.	11.68	1.10
08.0500	Health and safety	Labour costs				5.07			4.10		5.07	0.20
		Capital				0.61			0.80		0.61	0.20
		Expenses				1.05			0.70		1.05	0.40
		Contingency				0.67			0.70		0.67	0.10
		Subtotal	n.a.	n.a.	n.a.	7.40	b)	n.a.	6.30	n.a.	7.40	0.90
08.0600	Demobilisation	Labour costs				0.22			0.10		0.22	0.20
		Capital				0.03			0.00		0.03	0.00
		Expenses				0.05			1.20		0.05	0.50
		Contingency				0.03			0.10		0.03	0.00
		Subtotal	n.a.	n.a.	n.a.	0.33	b)	n.a.	1.40	n.a.	0.33	0.70
Total:			90.79	10.46	b)	34.02	b)	7.00	28.30	b)	34.02	5.60

a) Included into item 02.0100

b) Included into the total cost of decommissioning, not specified for given area

c) In case of Bulgaria these costs are solely contined to the Final Shutdown, Preparation of Safe Enclosure and partly for Safe Enclosure Stages

Table 4-20. Research and development costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
09.0100	Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment	Labour costs				1.63			0.10		1.63	0.30
		Capital				0.75			0.00		0.75	0.80
		Expenses				0.46			0.10		0.46	0.20
		Contingency				0.28					0.28	0.10
		Subtotal	a)	n.a.	n.a.	3.12	n.a.	n.r.	0.20	n.a.	3.12	1.40
09.0200	Simulation of complicated work on model	Labour costs				1.30			0.10		1.30	0.10
		Capital				1.00			1.50		1.00	0.30
		Expenses				0.53			0.10		0.53	0.10
		Contingency				0.28			0.20		0.28	0.10
		Subtotal	a)	n.a.	0.00	3.11	b)	n.r.	1.90	n.a.	3.11	0.60
Total:			a)	n.a.	9.50	6.23	4.20	n.r.	2.10	9.50	6.23	2.00

a) Included into item 08.0200
b) Included into the total cost of decommissioning, not specified for given area

Table 4-21. Fuel and nuclear material costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
10.0100	Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	a)	n.a.	n.r.	n.r.	n.a.	2.44	n.r.	n.r.	n.a.
10.0200	Intermediate storage	Labour costs		0.40								
		Capital		10.40								
		Expenses										
		Contingency										
		Subtotal	34.00	10.80	n.a.	n.r.	n.r.	n.a.	n.r.	n.a.	n.r.	n.a.
10.0300	Dismantling/disposal of temporary storage facility	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.r.	n.a.	n.r.	n.r.	n.a.	n.r.	n.a.	n.r.	n.a.
10.0400	Preparation for transfer of fuel or nuclear material from intermediate storage to final disposition	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.r.	n.a.	n.r.	n.r.	n.a.	n.r.	n.a.	n.r.	n.a.
10.0500	Dismantling/disposal of intermediate storage facility	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.r.	n.a.	n.r.	n.r.	n.a.	24.44	n.a.	n.r.	n.a.
Total:			34.00	10.80	b)	0.00	0.00	11.00	26.88	b)	0.00	n.a.

a) Included into item 02.0100
b) Included into item 01

Table 4-22. Other costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
11.0100	Owner costs	Labour costs		1.49		0.52					0.52	
		Capital		1.26		1.28					1.28	
		Expenses				0.10					0.10	
		Contingency				0.19					0.19	
		Subtotal	a)	2.75	n.a.	2.09	b)	0.00	0.00	n.a.	2.09	0.00
11.0200	General, overal (not specific) consulting costs	Labour costs				0.11					0.11	
		Capital				0.01					0.01	
		Expenses				0.03			0.50		0.03	
		Contingency				0.01			0.10		0.01	
		Subtotal	a)	n.a.	n.a.	0.16	b)	0.00	0.60	n.a.	0.16	1.00
11.0300	General, overal (not specific) regulatory fees, inspections, certifications, reviews, etc.	Labour costs		0.14		0.11					0.11	
		Capital		0.02		0.01					0.01	
		Expenses		1.80		0.03			2.00		0.03	
		Contingency				0.01			0.20		0.01	
		Subtotal	0.78	1.96	n.a.	0.16	b)	0.00	2.20	n.a.	0.16	1.20
11.0400	Taxes	Labour costs				0.00					0.00	
		Capital				0.14					0.14	
		Expenses				1.35					1.35	
		Contingency				0.15					0.15	
		Subtotal	n.a.	n.a.	n.a.	1.64	n.a.	n.a.	n.a.	n.a.	1.64	42.00
11.0500	Insurances	Labour costs		0.32		0.00					0.00	
		Capital		0.09		0.14					0.14	
		Expenses				1.35			2.00		1.35	
		Contingency				0.15			0.20		0.15	
		Subtotal	a)	0.41	n.a.	1.64	b)	n.a.	2.20	n.a.	1.64	0.00
11.0600	Overheads and general administration	Labour costs				1.63					1.63	
		Capital				0.20					0.20	
		Expenses				0.33					0.33	
		Contingency				0.21					0.21	
		Subtotal	a)	n.a.	n.a.	2.37	b)	0.00	1.63	n.a.	2.37	0.70
11.0700	Contingency	Labour costs				0.00					0.00	
		Capital				1.49					1.49	
		Expenses				1.35					1.35	
		Contingency				0.28					0.28	
		Subtotal	a)	n.a.	n.a.	3.12	b)	n.a.	25.60	n.a.	3.12	21.00

(cont)

Table 4-22. Other costs (SE)

Cost item	Cost item name	Cost groups	Decommissioning costs in MUSD/1998									
			Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
			440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
11.0800	Interest on borrowed money	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.	n.a.	n.a.	n.a.	n.r.	0.00	0.00	n.a.	n.a.	0.00
11.0900	Asset recovery: Resale/ transfer of general equipment and material	Labour costs										
		Capital										
		Expenses										
		Contingency										
		Subtotal	n.a.		n.a.	n.a.	0.00	0.00	0.00	n.a.	n.a.	0.00
Total:			0.78	5.12	25.60	11.18	0.20	17.10	32.23	23.00	11.18	65.90

a) Included into item 08.0200

b) Included into the total cost of decommissioning, not specified for given area

c) In case of Bulgaria these costs are solely contined to the Final Shutdown, Preparation of Safe Enclosure and partly for Safe Enclosure Stages

If safe enclosure is limited to one reactor shaft only as in Slovakia, the extent of the pre-decommissioning actions and related cost are comparable to the results in the immediate decommissioning option.

For the individual units in Finland, Hungary and Slovakia, the estimated costs are identical for both the options and in case of the Slovakia for both models.

4.4.2. Costs of facility shutdown activities

Facility shutdown costs are in some cases higher in the immediate decommissioning option while in other cases equal in both the immediate and the safe enclosure option. In the immediate decommissioning option, some projects consider during the facility shutdown period a decontamination of the reactor vessel and the primary loop. Significant cost differences may result from differences in labour costs or from the duration of the facility shutdown period that may vary from 3 to 5 years per one unit. Significant differences may also result from the number of personnel that is considered to perform all activities during this period.

In some projects, after plant shutdown a possible re-use of the technological equipment in other facilities was assessed. Currently, in most cases the exact scope of the equipment and its reuse could not be defined, however. Two countries (Germany and Hungary) consider that electrical and other equipment (e.g., equipment that was installed as a result of safety improvement measures) may potentially be reused.

It may be assumed that asset recovery in the safe enclosure option may result in less revenue than in the immediate decommissioning option.

4.4.3. Costs of procurement of general equipment and material

Nearly no difference may be detected in the costs for general equipment and material required in both decommissioning options. Any difference could be due to new equipment that may be required in the safe enclosure option. For the two models in the Slovak Republic, the costs are equal.

4.4.4. Costs of dismantling activities

Based on the reported figures, the dismantling costs vary from 7 to 61 % of the total decommissioning costs in the safe enclosure option, while between 13 and 42 % in the immediate decommissioning option. Differences between models 230 and 213 result from the higher material inventory of model 213. Costs for dismantling and decontamination are higher for model 213, therefore.

Asbestos occurs to a higher or to a lesser extent in nearly all units. The highest cost estimate for the removal of asbestos is 3.9 MUSD (Hungary). It includes removal, transport and final disposal of the asbestos or asbestos-containing materials. Decontamination of the internal surfaces of the stacks is not considered in either of the options, except for Bulgaria.

4.4.5. Waste processing, storage and disposal costs

Waste processing, storage and disposal costs are higher for the immediate decommissioning option than for safe enclosure, and may, based on the reported figures, vary from 3 to 50 % of the total decommissioning costs in the safe enclosure option, while between 20 and 42 % in the immediate decommissioning option.

4.4.6. Site security, surveillance and maintenance costs

Costs of site security, surveillance and maintenance are higher in the safe enclosure option due to the increased number of inspections and the activities that have to be carried during the 20 to 70 years' period of safe enclosure. As a result and based on the reported figures, the costs for site security, surveillance and maintenance can run up from 2 to 7 % of the total decommissioning costs in immediate decommissioning to 5 to 34 % in the safe enclosure option.

4.4.7. Site restoration, cleanup and landscaping costs

Based on the evaluations given in paragraphs 4.2.7 and 4.3.7, the costs for site restoration, cleanup and landscaping activities may considered to be independent of the selected option. Demolition costs for the model 213 are about 30 % higher due to the larger concrete volumes.

4.4.8. Project management, engineering and site support costs

No significant differences in project management, engineering and site support costs may be detected, except for Armenia where the figures also include other than project management costs.

4.4.9. Research and development costs

Research and development costs are similar for both options. In deferred decommissioning, many countries ignore research and development activities. It is considered that after the period of 20 to 70 years of safe enclosure, a lot of experience and practice will have been acquired, technologies and tools will be more mature and reliable, and most of them would be commercially available.

4.4.10. Fuel and nuclear material costs

The variety of costs shown for both options result from the different approaches and boundary conditions.

4.4.11. Other costs

When comparing both decommissioning options, no significant differences could be detected for this cost group. Assessments in Finland and Slovakia are identical for immediate decommissioning, and very similar for the safe enclosure option. In Finland and Hungary other costs are higher for the safe enclosure option, however.

5. COLLECTIVE DOSE ESTIMATION

The management of collective dose uptake during decommissioning activities may have an important impact on the decommissioning costs especially considering manpower requirements but also relating to required equipment for remote dismantling. Up to now, except for some of the facilities that have been shutdown, no study has been accomplished in any of the countries in order to analyse the doses absorbed by the personnel relating to the global decommissioning operations and considering detailed ALARA analyses during progress of the decommissioning work. There is also no practical experience in calculating individual and collective doses from the recycling of metals from the dismantling of nuclear installations. The data provided in the next Sections give an overview of the currently available information relating to the subject.

5.1. IMMEDIATE DECOMMISSIONING

Except of Germany, to estimate the collective dose for the decommissioning operations, dose uptake during plant maintenance and modification activities were used as a reference. In the German case, detailed ALARA optimisation was performed during the planning phase and is continuously refined during the current decommissioning operations [27]. An overview of the provided collective dose figures is shown in Figure 5-1. The average value for these collective dose figures, considering similar and accepted reference conditions, is about 19 man Sv, the maximum value being 34 man Sv, in case of the model 270 in Armenia.

The relatively low value for the German model 230 (8 man Sv) may be explained by the fact that these units were prematurely shutdown without reaching their design lifetime. The relatively lower dose for the Finnish units results from their strategy to remove and dispose the reactor pressure vessel and its internals as well as the steam generators in one piece.

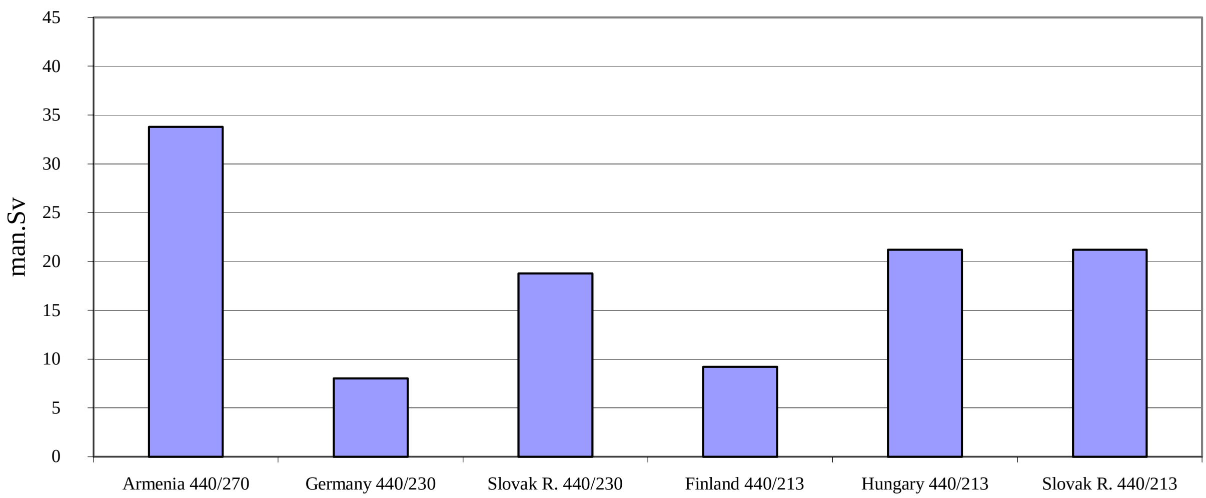

Figure 5-1. Estimated collective dose equivalent (ID).

5.2. SAFE ENCLOSURE

In this option, the collective doses are significantly lower than for immediate decommissioning as indicated in Figure 5-2. Averaging the results on a yearly basis makes no sense in this case, as the duration of the safe enclosure period may vary from 20 to 70 years. The lowest provided value is seen in Finland, i.e., somewhat higher than 2 man Sv (enclosure period of 20 years and one-piece removal of reactor pressure vessel, internals and steam generators being the specific decommissioning strategy adopted in Finland), the highest one 21 man Sv in Slovakia (enclosure period of 50 years).

6. DECOMMISSIONING PROJECT SCHEDULING

The shutdown period of the units varies from 3 to 5 years depending on the type and location of the intermediate storage and the characteristics of the license. Practical decommissioning activities are considered to commence after this shutdown period. Global decommissioning schedules include both time periods.

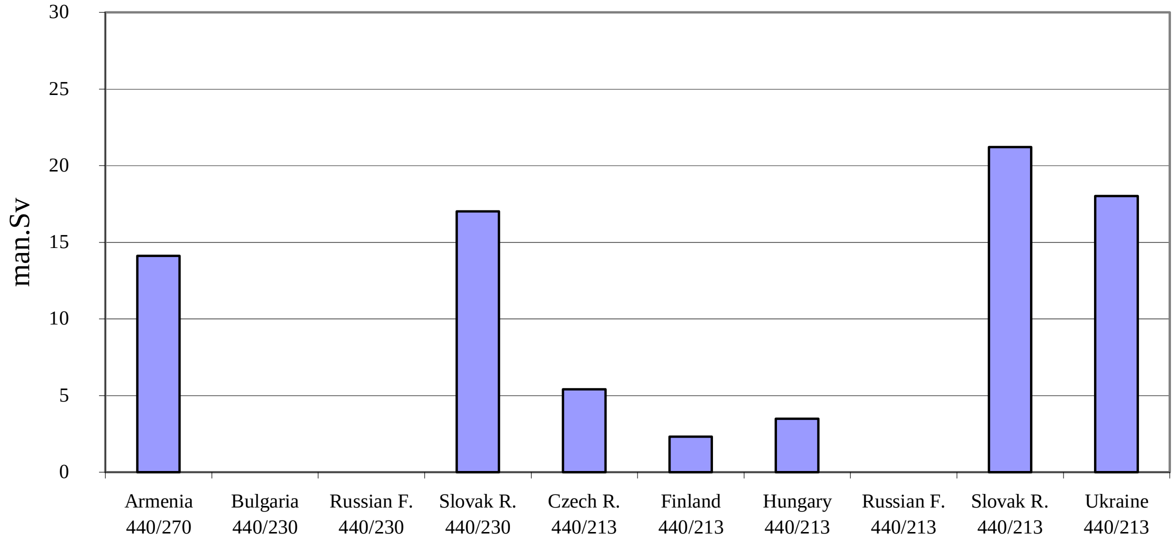

Figure 5-2. Estimated collective dose equivalent (SE).

6.1. IMMEDIATE DECOMMISSIONING

Time requirements for immediate decommissioning are well represented in Figure 6–1. Also the money flow that may be required during the various years of the decommissioning period is indicated.

It results from the figure that the duration of the decommissioning period may vary from 12 to 25 years. The shortest time period is calculated for Armenia, i.e., 12 years. The longest decommissioning time period is planned in Finland.

6.2. SAFE ENCLOSURE

Figure 6-2 shows the expected money flow as a function of the decommissioning time in the safe enclosure option. The safe enclosure period is the most essential time period; its duration may vary from 20 to 70 years:

Armenia:	50 years;
Bulgaria:	35 years;
Czech Republic:	50 years;
Finland:	20 years;
Hungary:	70 years;
Russian Federation:	30 years for both models;
Slovakia:	30 years for both models;
Ukraine:	30 years.

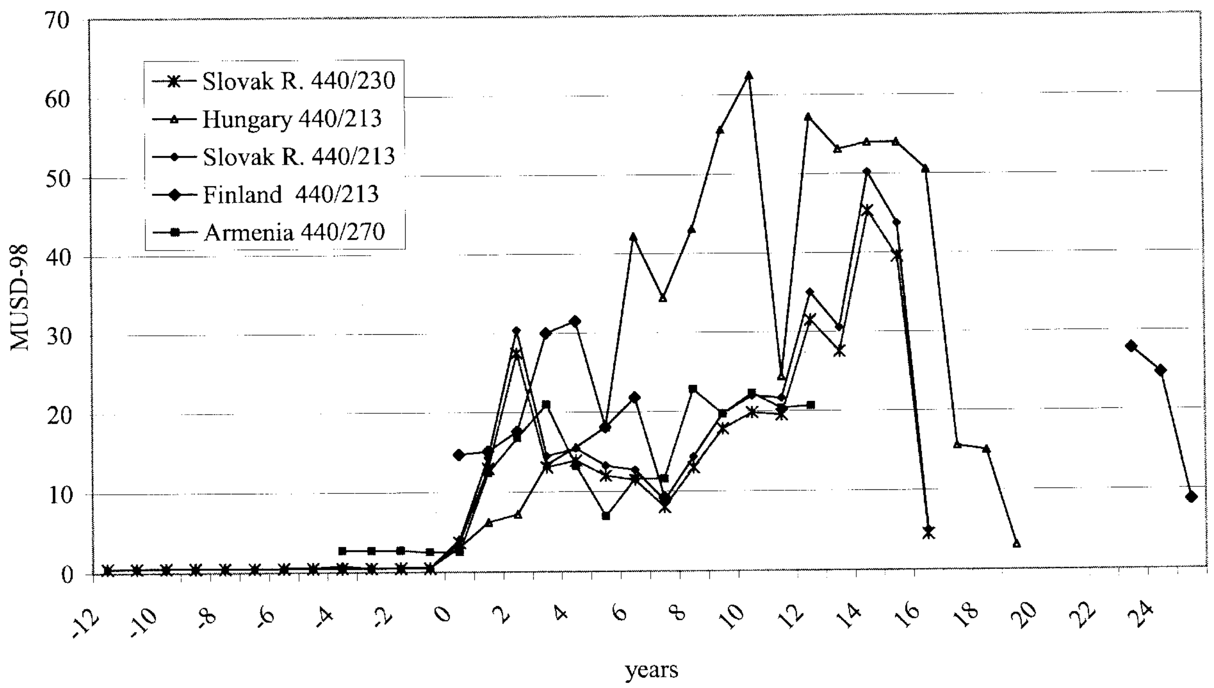

Figure 6-1. Estimated expediture profile (ID).

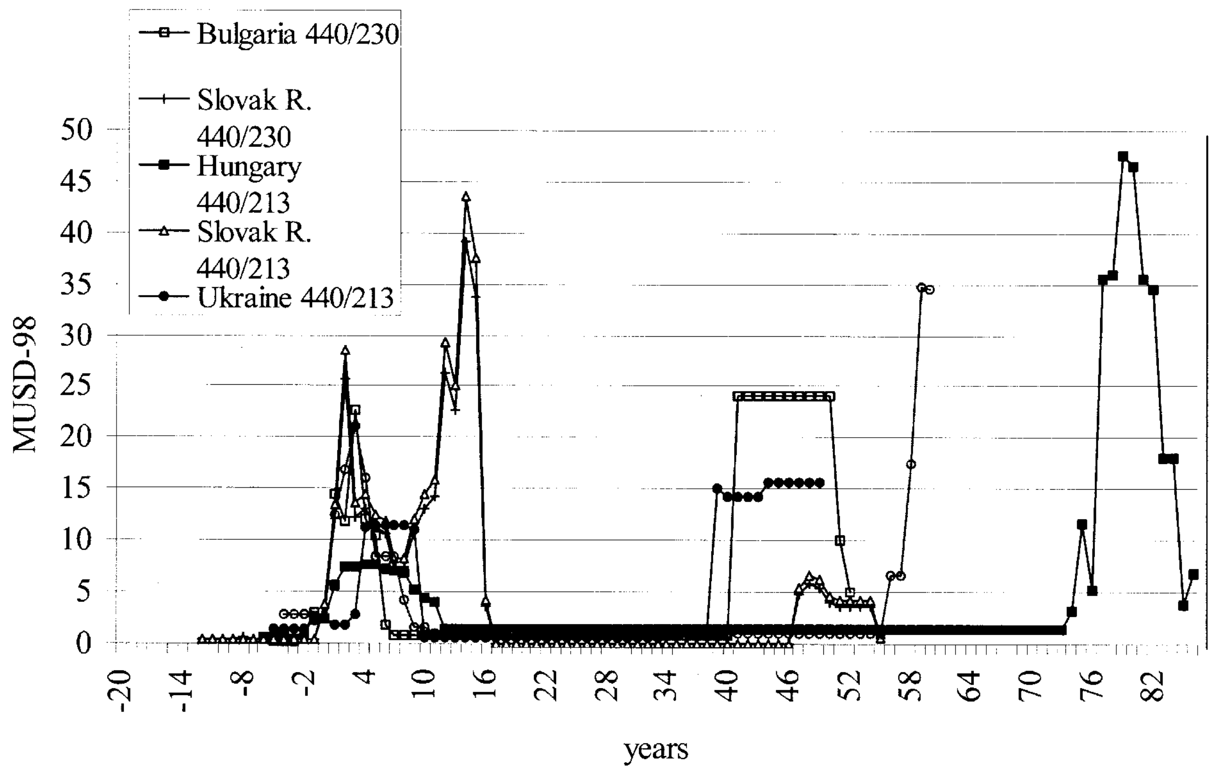

Figure 6-2. Estimated expediture profile (SE).

7. CORRELATIONS WITH EARLIER COST STUDIES

In practice, no new decommissioning cost assessments were accomplished within this study, but data of existing studies were requested to be processed according to the principles of the reference document [2]. It is not recommended, therefore, to perform any comparison with sources of the data that were provided, i.e. with previous versions of the national studies. It would be interesting, however, to compare the results of this study with data that were published in the international literature.

As a result, a comparison was made with data issued in earlier publications of the IAEA and the OECD.

7.1. IAEA PUBLICATIONS

Decommissioning costs of WWER–440 NPPs were included in [1], and were presented as follows:

(a) 100-400 USD’97/kWe for the immediate decommissioning option, (up to 1,200 USD’97/kWe for the Greifswald NPP in Germany); and

(b) 250-500 USD’97/kWe for the safe enclosure option.

As mentioned before, at this stage of cost estimating in the participating countries, overall comparisons seem to be premature and it is necessary to look at the detail of each cost item, the reason for this being the different scopes that are included and the limited detail of cost data that could be made available.

If it is emphasised, however, to make any restricted correlation, Figures 7-1 and 7-2 show estimated specific decommissioning costs using the data provided for the present study (currency exchange rate is different from the previous study). The resulting figures range between:

(a) 200-700 USD’98/kWe for the immediate decommissioning option (up to 1,700 USD'98/kWe for the Greifswald NPP in Germany); and

(b) 250-550 USD’98/kWe for the safe enclosure option.

Despite the restrictions indicated above, a rather good agreement between the results in both documents exists.

7.2. OECD PUBLICATIONS

In the framework of the OECD/NEA Co-operative Programme on Decommissioning a Report from the Task Group on Decommissioning Costs was published in 1991 [28]. In this report the main values and ranges of the eleven cost groups as well as of the cost categories are summarised for the two decommissioning options (immediate decommissioning and safe enclosure) respectively. The OECD/NEA study data refer to PWRs in general.

Considering the same restrictions relating to the data provided for the current document as mentioned in the foregoing paragraph, in Tables 7-1 and 7-2 a comparison is given between the OECD/NEA cost group figures and the data from the current study. By converting to percentage values, extreme data were not excluded from the initial data set that raised some suspicion. If the overlapping or extreme cost items within the WWER-440 data are removed from the comparison, no significant deviations may be identified between the cost groups.

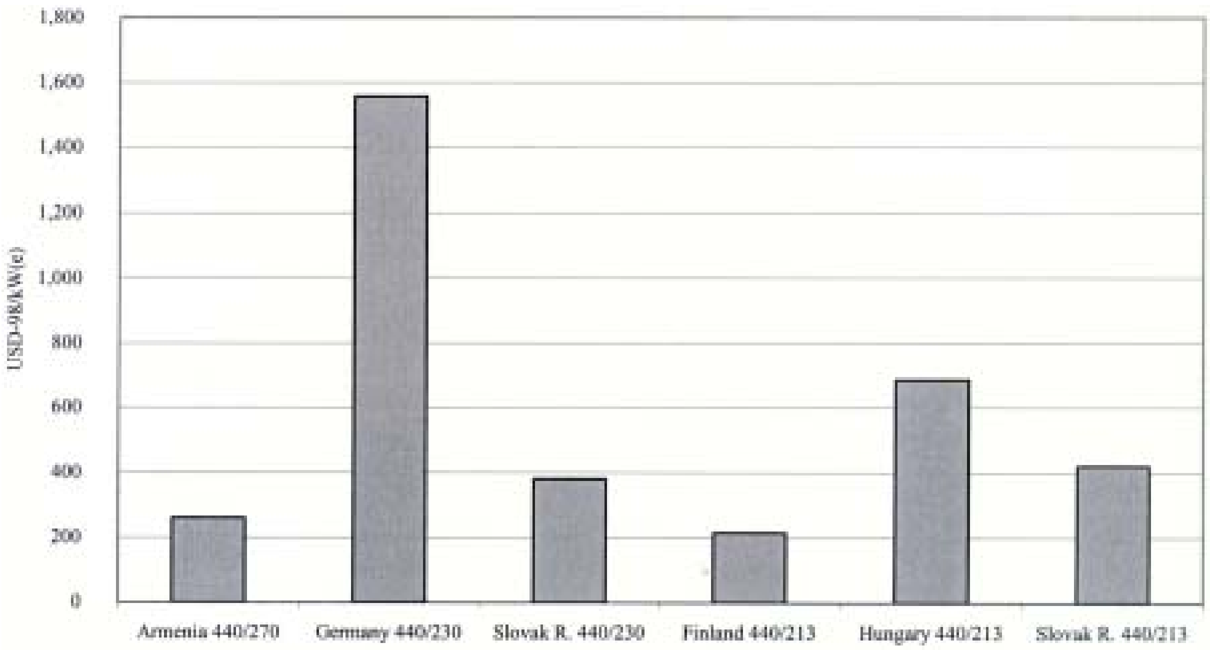

Figure 7-1. Estimated specific decommissioning costs (ID).

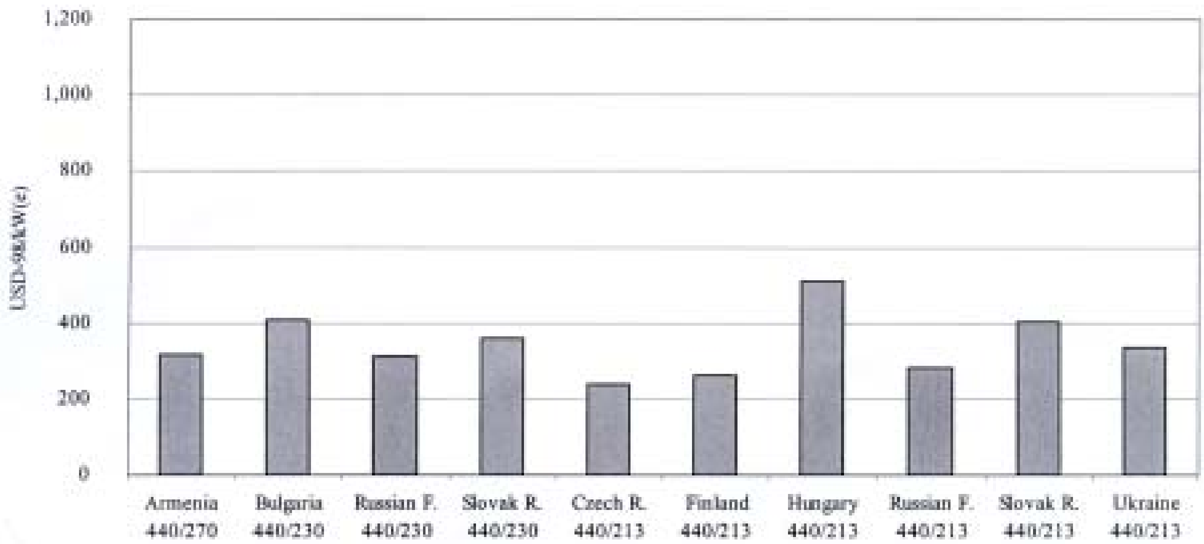

Figure 7-2. Estimated specific decommissioning costs (SE).

Based on Tables 7–3 and 7-4, the ratios of labour costs, capital costs and expenses indicated in the OECD report may be compared with the results of the current study. It should be stressed that only for the Slovakian NPPs costs were shown in all cost categories providing acceptable means for comparison. For some cost items, also Hungary and Ukraine provided costs distributed over the various cost categories. As a result, only these data were selected.

The tables show minor differences in capital, equipment and material costs in case of immediate decommissioning. In practice, the results of the current WWER-440 study are for all three cost categories within the OECD projects range. In the safe enclosure option the differences are more significant.

Table 7-1 Ranges within total cost groups (Immediate decommissioning)

	Cost Items	Range of Total Costs (%)	
		OECD Projects	WWER-440 Projects
1	Pre-decommissioning Actions	0.4 - 7.1	0.0 - 3.4
2	Facility Shutdown Activities	0.0 - 13.8	0.8 - 35.8
3	Procurement of General Equipment and Material	1.7 - 29.0	0.8 - 3.7
4	Dismantling Activities	13.5 - 48.5	13.2 - 42.4
5	Waste Processing, Storage and Disposal	2.2 - 11.2	19.5 - 41.5
6	Site Security, Surveillance and Maintenance	3.2 - 43.4	2.5 - 6.9
7	Site Restoration, Cleanup and Landscaping	0.1 - 5.1	0.0 – 27.0
8	Project Management, Engineering and Site Support	5.7 - 18.8	1.3 - 23.2
9	Research and Development	0.6 - 25.1	0.0 - 1.9
10	Fuel and Nuclear Material	0.0 - 0.0	0.0 - 16.0
11	Other Costs	0.6 - 14.7	0.0 - 5.2

Table 7-2 Ranges within total cost groups (Safe enclosure)

	Cost Items	Range of Total Costs (%)	
		OECD Projects	WWER-440 Projects
1	Pre-decommissioning Actions	4.3 - 14.3	0.0 - 8.2
2	Facility Shutdown Activities	13.3 - 13.3	0.0 - 11.4
3	Procurement of General Equipment and Material	1.4 - 2.8	0.0 - 3.1
4	Dismantling Activities	17.6 - 28.4	7.1 - 60.5
5	Waste Processing, Storage and Disposal	1.4 - 9.5	3.0 - 49.7
6	Site Security, Surveillance and Maintenance	22.6 - 31.2	0.0 - 33.5
7	Site Restoration, Cleanup and Landscaping	0.0 - 0.0	0.0 - 45.5
8	Project Management, Engineering and Site Support	4.6 - 8.4	0.0 - 35.1
9	Research and Development	1.2 - 1.5	0.0 - 3.8
10	Fuel and Nuclear Material	0.0 - 0.0	0.0 - 13.2
11	Other Costs	9.3 - 14.7	0.1 - 24.0

Table 7-3 Ranges within total cost categories (Immediate decommissioning)

	Cost Groups	Range of Total Costs (%)	
		OECD Projects	Selected WWER-440 Projects
1	Labour Costs	24.2 – 71.8	48.1 - 70.5
2	Capital, Equipment and Material costs	6.9 – 40.8	14.4 - 19.0
3	Expenses	5.3 – 38.3	15.1 - 32.8

Table 7-4 Ranges within total cost categories (Safe enclosure)

	Cost Groups	Range of Total Costs (%)	
		OECD Projects	Selected WWER-440 Projects
1	Labour Costs	36.9 - 62.6	7.9 - 68.6
2	Capital, Equipment and Material costs	13.2 - 21.7	14.3 - 43.7
3	Expenses	15.7 - 49.9	17.1 - 48.4

8. CONCLUSIONS

8.1. IMMEDIATE DECOMMISSIONING

A summary of the costs for the immediate decommissioning option is shown in Table 8-1 and in Figure 8-1, respectively. The costs vary between 213 MUSD (Armenia) and 1,370 MUSD (Germany). It is not easy to compare the given data as neither Armenia, Germany, nor Finland could comply with the proposed boundary conditions as mentioned in Section 3.1. The high figure for Germany is mainly due to the various factors included as described in the sub-sections of Section 4.2, e.g.:

- Post-operational and site operation activities until the end of the project, starting at the unplanned shutdown;
- Construction and operation of the interim storage, processing of operational waste and waste disposal costs;
- The costs for defuelling and interim storage of removed fuel in CASTOR containers;
- The higher labour costs as compared to other countries in the study.

Table 8-1. Decommissioning costs (ID)

Main cost item	Name of the main cost item	Decommissioning costs in MUSD/1998					
		Armenia 440/270	Germany 440/230	Slovak R. 440/230	Finland 440/213	Hungary 440/213	Slovak R. 440/213
01.	Pre-decommissioning actions	a)	29.4	7.4	7.4	9.2	7.4
02.	Facility shutdown activities	4.1	490.8	3.1	31.4	58.3	3.1
03.	Procurement of general equipment	4.0	10.9	7.2	8.2	9.4	7.2
04.	Dismantling activities	28.0	197.0	53.4	93.0	100.1	59.1
05.	Waste processing, storage and ..	53.3	498.1	106.9	42.7	262.1	113.3
06.	Site security, surveiullance and …	14.7	53.7	22.5	8.0	15.8	22.5
07.	Site restoration, cleanup and ..	25.0	14.5	75.1	n.r.	94.1	97.7
08.	Project managenment	49.2	17.5	34.0	6.0	26.4	34.0
09.	Research and development	a)	0.0	6.2	n.r.	2.6	6.2
10.	Fuel and nuclear material	34.0	58.0	n.r.	11.0	26.9	n.r.
11.	Other costs	0.2	n.a.	11.2	11.5	27.2	11.2
Total:		212.5	1369.9	327.0	219.2	632.1	361.7

a) Included into 08.0200

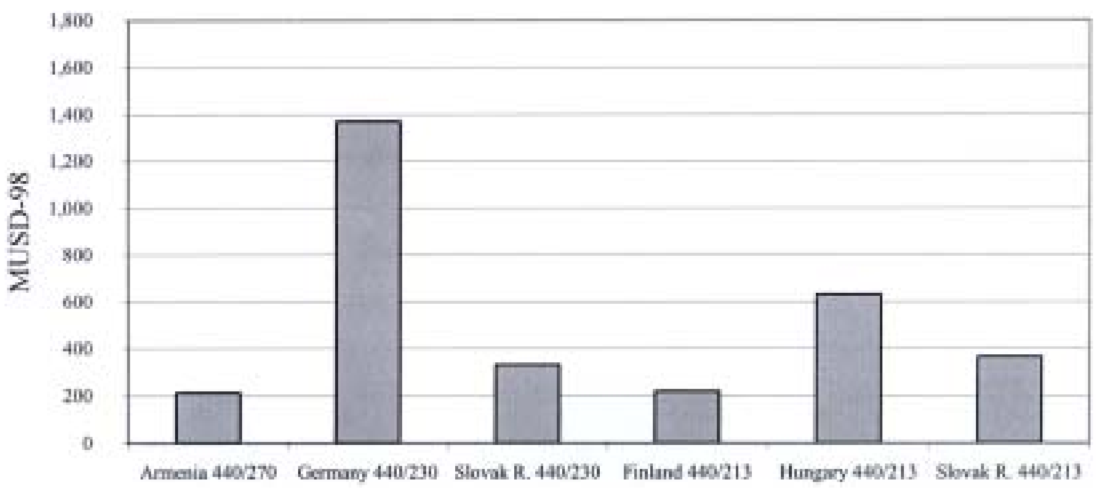

Figure 8-1. Summarised decommissioning costs (ID).

Among the other projects, the highest cost for immediate decommissioning is 632 MUSD (Hungary). As in Hungary, there is not yet any disposal facility available to accommodate the volumes of wastes from decommissioning, the costs included for disposal have been considered as referred to in OECD countries. This is also the reason why the identical model 213 units in Hungary and Slovakia show some essential differences in their decommissioning cost figures.

One of the most important parameters in decommissioning is the estimated amount of labour, assessed values for which are shown in Figure 8-2. The lowest labour demand is indicated by Finland, i.e., 2,800 man years. The Finnish scope of decommissioning only considers the radioactive parts of the plant, and labour requirements are reduced as the reactor pressure vessel and its internals as well as the steam generators are removed and stored as one piece.

Estimated cumulative costs for immediate decommissioning are given in Figure 8-3.

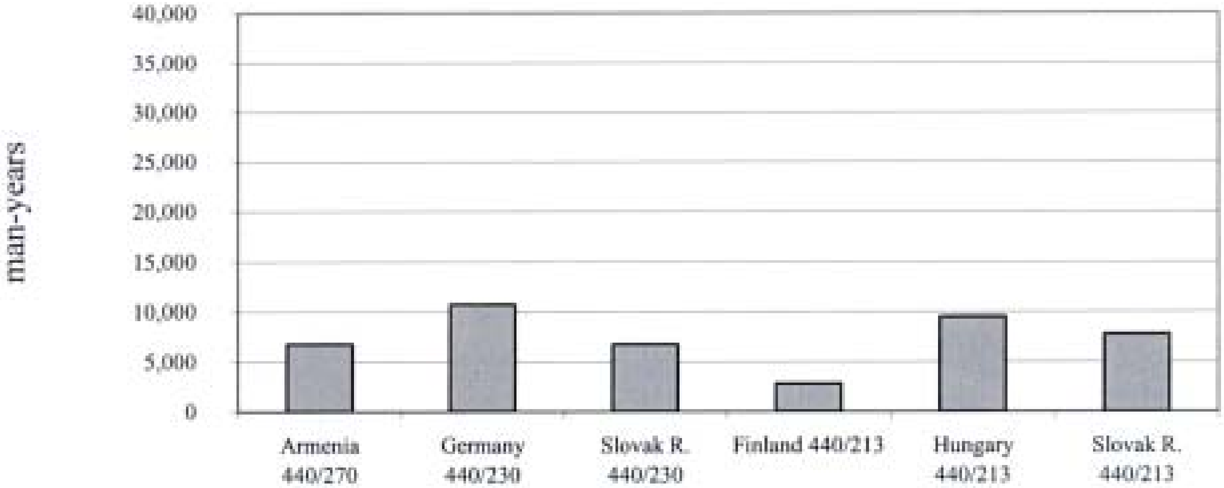

Figure 8-2. Estimated labour demand (ID).

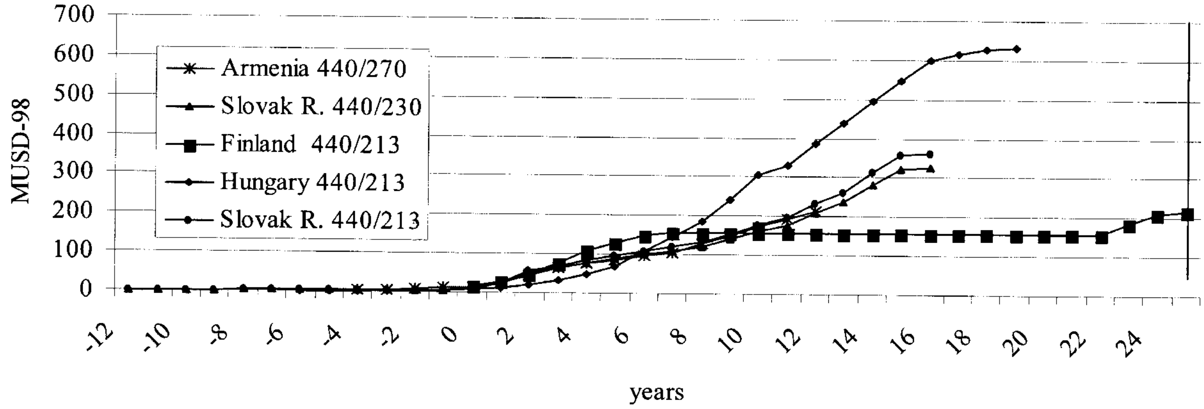

Figure 8-3. Estimated cumulative decommissioning costs (ID).

8.2. SAFE ENCLOSURE

A summary of the costs for the safe enclosure option is shown in Table 8-2 and in Figure 8-4, respectively. The costs vary between 210 MUSD (Czech Republic) and 469 MUSD (Hungary). Scattering is smaller than for immediate decommissioning. If only the total costs are considered, there seems to be remarkable agreement between the costs for the Bulgarian model 230 and the Hungarian model 213 NPPs, between the Armenian model 270 and the Russian model 213 plants, and the Russian model 230 and the Ukrainian model 213 units.

The higher figure for Hungary includes the decommissioning of the interim storage facility for spent fuel, the longer safe enclosure period (70 years), the costs for the facility shutdown operations and the disposal costs of decommissioning waste.

The lower figure for the Czech model 213 is mainly due to the reduced scope considered when compared to the other plants in the study.

Reported labour requirements for this decommissioning option are given in Figure 8-5. The Figure shows that for the Slovak reference plants, estimated labour costs for the model 213 are about 15 % higher than for the model 230 unit, which may be due to the higher material inventory for the model 213.

Estimated cumulative costs for the safe enclosure option are shown in Figure 8-6.

Table 8-2. Decommissioning costs (SE)

Main cost item	Name of the main cost item	Decommissioning costs in MUSD/1998									
		Armenia	Bulgaria	Russian F.	Slovak R.	Czech R.	Finland	Hungary	Russian F.	Slovak R.	Ukraine
		440/270	440/230	440/230	440/230	440/213	440/213	440/213	440/213	440/213	440/213
01.	Pre-decommissioning actions	a)	18.7	20.6	7.4	1.5	7.4	9.2	20.6	7.4	3.4
02.	Facility shutdown activities	4.1	27.1	b)	3.1	2.7	24.8	53.6	b)	3.1	6.9
03.	Procurement of general equipment	4.0	5.0	n.a.	7.8	3.4	8.2	10.0	n.a.	7.8	6.8
04.	Dismantling activities	28.1	151.9	165.2	55.4	14.9	83.0	83.0	148.7	61.3	27.9
05.	Waste processing, storage and ..	47.6	10.7	13.6	86.0	17.3	40.0	84.1	13.6	92.6	136.5
06.	Site security, surveiullance and …	24.1	47.3	b)	24.4	70.3	69.0	45.5	b)	24.4	13.0
07.	Site restoration, cleanup and ..	25.0	72.0	38.5	75.1	95.4	n.r.	94.1	34.6	97.7	6.8
08.	Project managenment	90.8	10.5	b)	34.0	b)	7.0	28.3	b)	34.0	5.6
09.	Research and development	a)	n.a.	9.5	6.2	4.2	n.r.	2.1	9.5	6.2	2.0
10.	Fuel and nuclear material	34.0	10.8	c)	0.0	0.0	11.0	26.9	c)	0.0	n.a.
11.	Other costs	0.8	5.12	25.6	11.2	0.2	17.1	32.2	23.0	11.2	65.9
	Total:	258.4	359.1	273.0	310.6	209.9	267.5	469.0	250.0	345.6	274.8

a) Included into item 08.0200
b) Included into the total cost of decommissioning, not specified for given area
c) Included into item 01
d) In case of Bulgaria cost items 03; 05; 08 and 11 are solely continued for Final Shutdown, Preparation of Safe Enclosure and partly for Safe Enclosure Stages
e) In case of Russia, at cost item 04, also waste treatement costs are included

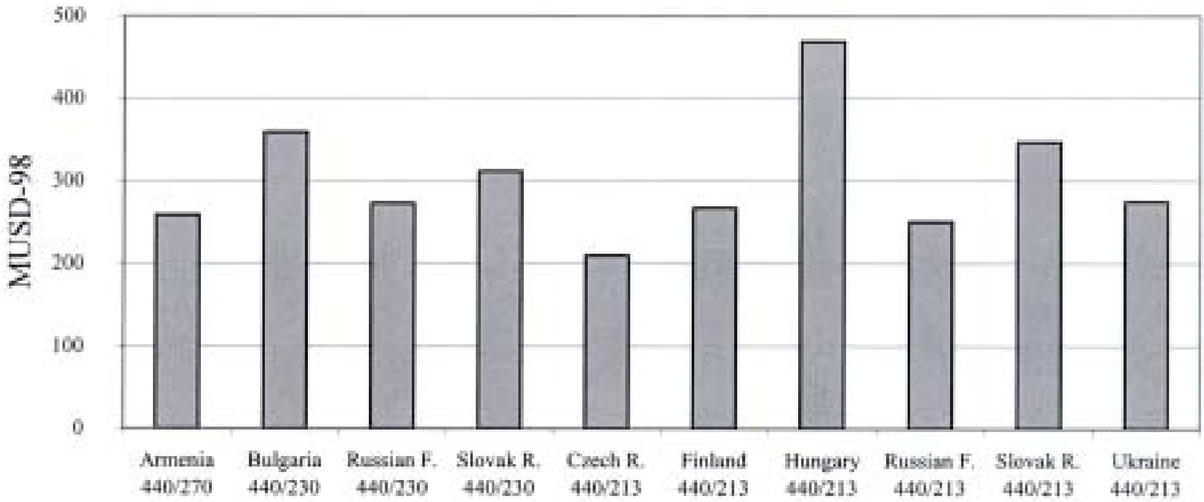

Figure 8-4. Summarised decommissioning costs (SE).

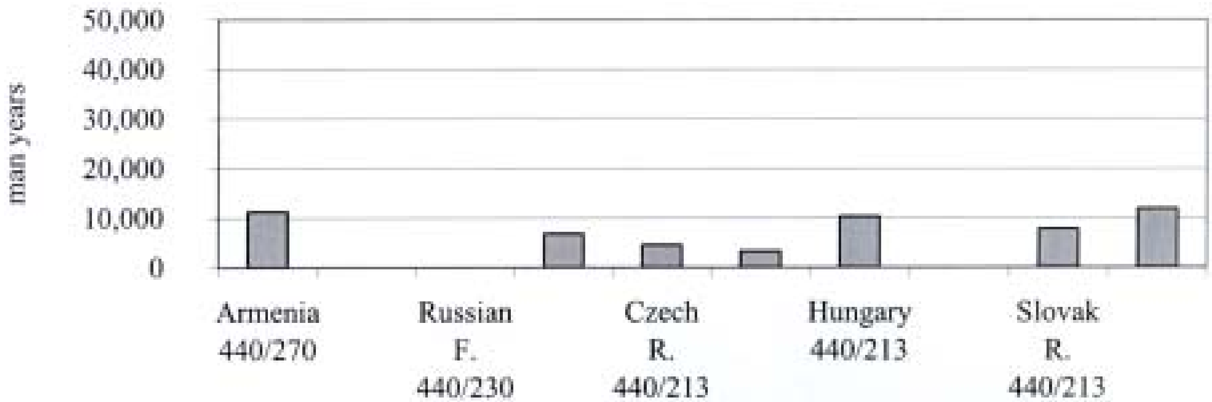

Figure 8-5. Estimated labour demand (SE).

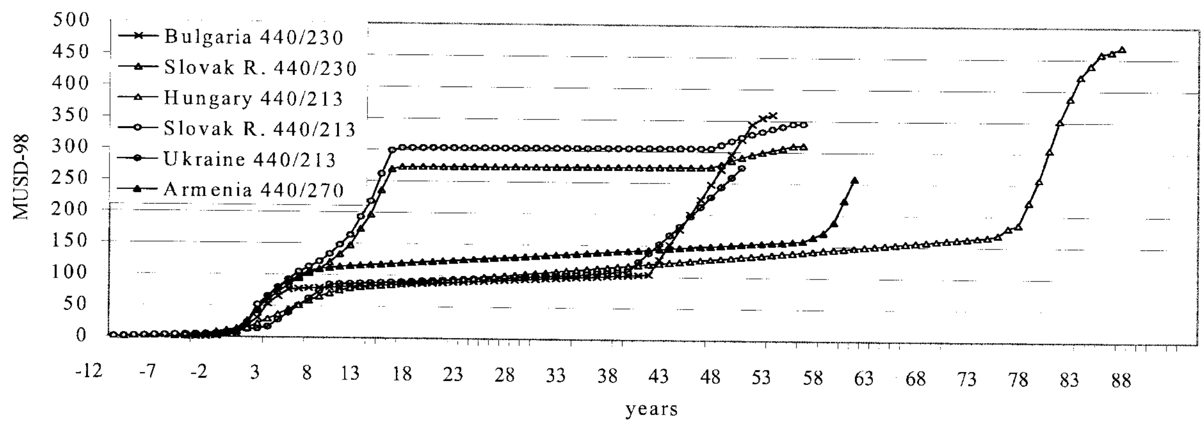

Figure 8-6. Estimated cumulative decommissioning costs (SE).

8.3. GENERAL CONCLUSIONS

The main objectives of this technical document were:

- To present the decommissioning costs of WWER-440 NPPs in a uniform manner, using the cost item and cost group system of the joint EC/IAEA/OECD-NEA Interim Technical Document on Nuclear Decommissioning, “A Proposed Standardised List of Items for Costing Purposes” [2]; and
- To provide a basis for understanding decommissioning costs differences in case of WWER-440 NPPs.

It was shown that the standardised list of items for costing purposes, using a set of well defined decommissioning items, may facilitate communication, promote uniformity and help to avoid inconsistency in results of decommissioning cost assessments.

The current document describes the first exercise in which decommissioning costs for NPPs were converted to and presented in accordance with the structure recommended in the referred document.

The document comprises a presentation and analyses of the costs for two decommissioning options for WWER-440 NPPs, i.e., immediate decommissioning and safe enclosure. The specific characteristics of individual cost items could be identified and understood. When interpreting individual cost items in the recommended cost structure, also the boundary conditions for the individual decommissioning projects were clarified.

The document presents the decommissioning costs of WWER-440 NPPs as they are currently available. For some cost items or sub-items large cost differences have been identified. It may be explained by the fact that in some countries certain cost factors are not yet well known, and that in practice no decision has yet been taken. Large differences may also result from different decommissioning strategies, alternative scope of decommissioning activities, or from differences in regulation as well. They might also result from uncertainties in converting costs from the existing structures to the newly proposed one, however.

The management of collective dose uptake during decommissioning activities may have an important impact on the decommissioning costs especially considering manpower requirements but also relating to required equipment for remote dismantling. Up to now, except for some of the facilities that have been shutdown, no study has been accomplished in any of the countries in order to analyse the doses absorbed by the personnel relating to the global decommissioning operations and considering detailed ALARA analyses during progress of the decommissioning work.

Cost estimating for decommissioning of nuclear facilities is a continuous task in each country. National regulatory authorities require a certain frequency of updating. Improvement of the quality of cost figures may be expected in the future, when the recommended cost structure will be widely used. The current document should therefore be considered as an interim document. It is recommended, to revisit this interim cost study in about three to five years. In addition, a more detailed description of the items comprised in the cost matrix of the reference document is recommended. It is expected that as a result of these recommendations and due to the periodic updating of cost estimates, future cost figures will become more precise.

Comparison of the cost groups (Labour costs; Capital, equipment and material costs; and Expenses) has demonstrated that about 50 % of the total decommissioning costs is due to labour requirements. Comparing the results with the OECD/NEA cost study results has shown quite good agreements. It may be concluded, therefore, that WWER-440 NPPs are certainly not “unique” from the point of view of their decommissioning costs.

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Annexes 1-9

STATUS REPORTS FROM THE PARTICIPATING MEMBER STATES

Annex 1

ARMENIA

1. Preliminary Decommissioning Plan Development

To develop a plan for the ANPP decommissioning, Armenian specialists together with experts from organisations as PNNL, funded by the US DOE, and SOGIN (Italy), funded by TACIS, EU, have considered several versions of preliminary decommissioning plans.

When preparing this document, it was decided to take, as a basic option, the study developed by the PNNL, which is most closely responding to the “Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations”, commonly published by IAEA, EC and OECD/NEA. Therefore, further on the data of the PNNL study will be used.

Three decommissioning alternatives were considered that are currently recognised by specialists:

(a) Immediate decommissioning (DECON);

(b) Safe enclosure (SAFSTOR);

(c) Entombment (ENTOMB).

A description of each of these alternatives is given.

Immediate Dismantlement (DECON)

The equipment, structures, and portions of the facility that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the operating license shortly (10-15 years) after cessation of operations.

Safe Enclosure (SAFSTOR)

The facility is placed in a safe, stable condition and maintained in that state until it is subsequently decontaminated and dismantled to levels that permit license termination. During this period the facility is left intact, but the fuel has been removed from the reactor vessel and radioactive liquids have been drained from systems and components and then processed. Radioactive decay occurs during this period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during decontamination and dismantlement.

Entombment (ENTOMB)

Radioactive structures, systems, and components are encased in a structurally long-lived substance, such as concrete. The entombment structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

The SAFSTOR/DECON alternative is similar to DECON, except that a safe enclosure period of 50 years precedes dismantlement.

The SAFSTOR/ENTOMB alternative is similar to ENTOMB, except that a safe enclosure period of 50 years precedes the dismantlement and entombment activities.

Two versions of SAFSTOR/DECON and SAFSTOR/ENTOMB alternatives are considered.

The differences between the SAFSTORE versions are:

- SAFSTORE (I) assumes that the spent nuclear fuel is moved into dry storage about 25 years after permanent shutdown, requiring continued operation of many of the plant safety and auxiliary systems (decontamination and dismantling of the plant is then delayed for another 25 years).
- SAFSTORE (II) assumes that the spent nuclear fuel is moved into dry storage about 7 years after permanent shutdown, allowing shutdown of all plant safety and most auxiliary systems (decontamination and dismantling of the plant is then delayed for 50 years).

The basic information for all variations is shown in Tables 1, 2, and 3.

The preferable variations for Armenia are DECON and SAFSTOR/DECON (II). Therefore, they are considered in more detail.

1.1 DECON

This alternative has four designated periods of time:

1. Planning and Preparation (5 years);
2. Defuelling and Deactivation (3 years);
3. Spent Fuel Management (4 years);
4. Dismantlement (5 years).

The 5-year planning and preparation period (Period 1) will precede the final reactor shutdown of the ANPP. During this period plans and procedures will be developed that will be carried out during decommissioning. Period 2 begins after the reactor has been shutdown for the last time. Reactor support systems that are no longer needed will then be shut down, deactivated, and put into a safe condition. In addition, the spent fuel storage facility will be expanded to accommodate all spent fuel on-site.

Management of the spent fuel and spent fuel pools will occur during the Period 3. Fuel from the last core must remain in the pools for a minimum of three years after final shutdown until it is sufficiently cooled down to permit transfer to the dry spent fuel storage. Also, during Period 3 the available low level waste storage facility will be upgraded to accommodate the current quantities of radioactive waste and the large quantities of D&D waste that will be generated during the active decommissioning period. This new facility will be designed for permanent disposal of low and intermediate level radioactive wastes.

Once the pool has been emptied, pool-related systems will be deactivated, and active decontamination and dismantlement will begin (Period 4). Large components will be removed from the reactor building and transported to the upgraded new on-site burial facility. The remaining large components (pressurizers, primary coolant pumps, steam generators, etc.) will be transported and buried as a whole. The smaller equipment (various pumps, valves, piping, heat exchangers, etc.) will be removed, size reduced, packaged, and compacted as required before transfer to the burial facility.

Waste currently stored in the intermediate level waste storage facility will be retrieved and treated as necessary, and then stored at the existing on-site waste facility. The reactor internals and the components currently stored in the high level waste storage cells in the reactor building will be transferred to the dry spent fuel storage.

Surfaces of structures will be decontaminated by washing and grinding, as appropriate, with the debris from these operations being transported to the burial facility. Once the structures are decontaminated, they will be demolished and buried in place. Buildings that were never contaminated will be left intact.

Detailed information of the decommissioning costs and other data on this alternative is shown in Table 4.

1.2. SAFSTOR (II)

This alternative has five distinct periods:

1. Planning and Preparation (5 years);
2. Defuelling and Deactivation (3 years);
3. Spent Fuel Management (4 years);
4. Safe Enclosure (50 years);
4. Dismantlement (3 years).

The Periods 1 to3 are virtually the same as the first three periods of the DECON alternative. However, for SAFSTOR (II) a 50 years safe enclosure period is inserted between the spent fuel management period and the dismantlement period. During the last two years of this safe enclosure period the new low level waste facility will be constructed.

The dismantlement period (Period 5) of SAFSTOR (II) is the same as the dismantlement period for the DECON alternative. Personnel radiation dose is, of course, significantly lower.

Detailed information of the decommissioning costs and other data on this alternative is shown in Table 5.

2. Radioactive Waste Management

Radioactive wastes generated during daily cleaning and decontamination of the restricted areas and rooms of the plant, during repair of equipment, during construction and repair activities in restricted areas, as well as spent sources of ionising radiation, instruments, and so on, are transported to the solid waste storage.

Radioactive wastes generated during the ANPP active water treatment from distillation, residues from evaporator wastes, and removed resins from Special Water Cleaning (SWC) filters, are transported to the liquid wastes storage (LWS).

The volume of each of these types of wastes is shown in Table 6.

The waste management costs for each D&D alternative is shown in Table 7.

2.1. Types of Radioactive Waste Storages at the ANPP

Several interim storage facilities are currently available as part of the site infrastructure. It may be possible to convert some of the facilities from a temporary storage facility to a final disposal area.

The ANPP has storage facilities for both solid and liquid radioactive wastes.

2.1.1. Solid Radioactive Waste Storage Facilities

Solid radioactive waste storage facilities are divided into:

- High level radioactive waste storage;
- Medium level radioactive waste storage;
- Low level radioactive waste storage.

High level waste is stored in the reactor building. The storage area consists of 380 cells, each of which is 0.18 m in diameter, 8.9 m deep, and 0.72 m high. Each cell is sealed by a cover. The storage capacity is 78.34 m^3.

Medium level radioactive waste is stored in the Special Building. Storage capacity is 1001.22 m^3.

The low level radioactive waste storage facility consists of two compartments, each measuring 27 x 36 x 8,9 m. The total storage volume is about 17,050 m^3.

2.1.2. Liquid Radioactive Waste

Liquid radioactive waste is stored in the Special Building. The liquid radioactive waste storage system includes:

- Six evaporator residue tanks, each with a volume of 550 m^3;
- One evaporator residue tank with a volume of 420 m^3;
- One tank of high level sorbents with volume of 420 m^3;
- Two low level sorbent tanks, each with a volume of 162 m^3;
- Three drain water tanks, each with a volume of 177.5 m^3;
- Two evaporator bottom storage tanks, each with a volume of 10 m^3;
- Liquid waste storage heat exchanger with a heat exchange surface area of 2.0 m^2;
- Three vacuum pumps
- Piping, equipment, and control measurement instrumentation.

There is also a deep evaporation facility at the ANPP intended to reduce the volume of evaporator residues by bulk evaporation of sludges, resulting in a solid waste product.

2.2. Possible Future Facilities

The capacity of several facilities is not adequate for the projected waste volumes. Additional LLW, ILW, and high level waste storage and disposal capacity may be needed for some D&D scenarios.

A key point in the development of off-site storage facilities is the availability of a suitable geology. There are no other sites available within Armenia that could get a high preference. It has been a general consideration of this plan, therefore, that the waste would remain on the ANPP site and would not be shipped to some other location.

Several basic decommissioning alternatives are being evaluated. For each alternative a specific waste management plan has been identified for each of the waste types. The selected scenario for the management of each waste type is shown in Table 8.

3. Spent Nuclear Fuel Management

3.1. Current Spent Nuclear Fuel Storage Practice

Currently, there are two types of spent nuclear fuel storages used at the ANPP: wet storage cooling pools and a dry storage facility. The last started to receive spent nuclear fuel in August 2000. Its capacity is 612 fuel assemblies.

3.2. Spent Nuclear Fuel Interim Storage Requirements

At the end of 1999, there were about 1,064 spent nuclear fuel assemblies stored in the cooling pools (364 in the Unit 1 cooling pool and 700 in the Unit 2 cooling pool). On average, an additional 110 assemblies are discharged from the Unit 2 reactor each year. Finally, when the Unit 2 reactor will be permanently shut down, the final core discharge will equal to 349 assemblies. The total inventory of spent nuclear fuel assemblies, assuming five more years of Unit 2 operation (through 2004), will therefore be 1,963, and with ten years of operation (through 2010) 2,623.

As it can be seen, no new investments for expanding spent nuclear fuel storage are required if Unit 2 will be operated for only five more years. However, if it is operated untill 2010, the interim storage capacity at the plant should be expanded. Expansion can be obtained by either re-racking the spent fuel pools into higher density storage configurations or by enlargement of the dry spent fuel storage facility. This cost for expanding the spent fuel storage capacity is a plant operating cost, however, and is not included in the cost of decommissioning.

3.3. Expansion of On-Site Dry Storage

In this option, the existing dry storage facility will be expanded to enable dry storage of all spent nuclear fuel on the ANPP site. While this option requires a significant investment, it has the advantage to enable elimination of all nuclear safety systems within the ANPP and generate minimum annual operation and maintenance costs.

As shown in Table 9, the capital cost of this option is estimated at US$ 25.5 million to US$ 33.7 million, depending on whether the last year of operation for Unit 2 is 2004 or 2010, respectively.

3.4. Option for a New Off-Site Dry Storage Facility

Under this option, the storage facility would be constructed in Armenia but not within the site of the ANPP. Compared to the previous options, this option has a number of disadvantages. The cost of this option is summarised in Table 9.

3.5. Interim Storage by Another Country

Under this option, the spent nuclear fuel would be shipped to a foreign country for long term interim storage. The advantage of this option is that the regulatory aspects and the physical infrastructure required for the interim storage of spent nuclear fuel should not be provided by Armenia but by another country that, in the ideal case, has the infrastructure already in place. The cost includes transportation of the spent nuclear fuel to the other country and interim storage of the fuel for an indefinite time period. A cost estimate for this option is summarised in Table 9.

3.6. Permanent Disposition in a Foreign Country

This option is similar to the former one except that the foreign country should provide both interim storage and final disposition of the spent nuclear fuel. The cost includes transportation of the spent nuclear fuel to the other country and its permanent disposition. The cost estimate for this option is summarised in Table 9.

4. Data from the SOGIN study

In a specific study relating to the decommissioning costs of the ANNP, SOGIN considered three options:

1. SAFSTORE, which is called the ”base-case” as it is preferred for the ANPP above the other options. It was developed in details.
2. FULL-STAFF SAFSTORE option, which is called the “full-staff case”.
3. “DECON-case” of the immediate decommissioning option.

The decommissioning costs for these options are 816 MECU, 953 MECU, and 720 MECU, respectively, with the same 20 % contingency included for each option.

It was also assumed that spent fuel management and disposal costs are the same for all three options and equal to 200 MECU.

The only difference between the first two options, resulting in a different cost, is that for the “full-staff case” the assumption was made that until 2013 the number of ANPP personnel should gradually reduce from 1900 to 1200, with a further abrupt dropping to 200 in 2020. In the “base-case” it was assumed that the personnel number drops abruptly to 300 immediately after the permanent shutdown stage is started.

The comparison of these two cost estimates (SAFSTORE II and “base-case”) shows that the SOGIN estimate is substantially higher than the estimates for any of the decommissioning alternatives evaluated by the PNNL.

In practice, the SOGIN cost estimate for the “NPP Dismantling and Site Release” phase is much higher than the PNNL estimate.

The data relating to the PNNL SAFSTOR (II) option and the SOGIN “base-case” option decommissioning costs, time schedule, manpower and collective dose are given in Table 10.

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[1-4] Assessment of the Armenian NPP Decommissioning Costs, elaborated under the TACIS Project EAR 9801, Task 4.2, May 2001.

Table 1. Decommissioning Costs by Alternative (Millions of 1999 US Dollars)

PERIOD NAME	Alternative					
	DECON	SAFSTOR (I)	SAFSTOR (II)	ENTOMB	SAFSTOR/ENTOMB (I)	SAFSTOR/ ENTOMB (II)
Facility D&D						
D&D Planning & Preparation	11	11	11	10	10	10
Defuel and Deactivation	23	23	23	23	23	23,
Spent Fuel Pool Operations	22	119	22	22	119	22
Safe Storage Period	-	33	52	-	33	52
Dismantlement	58	58	58	-		-
Entombment Preparation	-	-	-	31	30	30
Entombment Period	-	-	-	9	9	9
Totals	115	245	166	95	225	146
Waste Management						
Low Activity Waste	17	19	17	4	4	4
Intermediate Activity Waste	13	14	13	11	11	11
High Activity Waste	8	2	2	5	4	4
Liquid Waste	1	1	1	1	1	1
Totals	39	36	33	21	20	20
Spent Nuclear Fuel Management	34	34	34	34	34	34
Clean Demolition	25	25	25	25	25	25
Total Cost	213	339	258	174	304	225

Table 2. Worker-Years By Decommissioning Alternative (Includes 25% Contingency On Labor)

	Alternative					
	DECON	SAFSTOR (I)	SAFSTOR (II)	ENTOMB	SAFSTOR/ ENTOMB (I)	SAFSTOR/ ENTOMB (II)
Worker-Years	6,749	15,569	11,249	6,149	14,969	10,649
Worker- Years/year	397	232	168	95	130	93

Table 3. Operational Radiation Exposure (mSv) by Decommissioning Alternative

	Alternative					
	DECON	SAFSTOR 1	SAFSTOR 2	ENTOMB	SAFSTOR/ ENTOMB (I)	SAFSTOR/ ENTOMB (II)
Worker-mSv	33,824	27,780	14,124	13,053	27,595	12,931
Worker-mSv/year	1,990	415	211	201	240	112

Table 4. Decommissioning Costs for the DECON Alternative

	Costs (S 000)					Waste Vol m^3	Crew Hours	Person-Hours	Person-mSv
Periods and D&D Activities	Decon	Remove	Package	Other	Total				
PERIOD 1: Planning and Preparation (5 years)									
Utility Staff	0	0	0	1,287	1,287	0	0	0	0
DOC Staff	0	0	0	5,043	5,043	0	0	0	0
Special Tools and Equipment	0	0	0	2,768	2,768	0	0	0	0
Totals for PERIOD 1	0	0	0	9,097	9,097	0	0	0	0
PERIOD 2: Defuel and Deactivate (3 years)									
Removal of RPV Internals	0	115	155	0	270	195.64	2,465	22,183	1,052
Chemical Decontamination	2,365	0	0	0	2,365	130.26	3,520	21,120	457
Disposal of Concentrated Boron Solution	895	0	1	0	896	13.59	3,936	11,808	120
Dry Active Waste	0	0	14	0	14	131.68	0	0	0
Utility Staff	0	0	0	6,830	6,830	0	0	449,280	4, 493
DOC Staff	0	0	0	3,465	3,465	0	0	0	0
Regulatory Costs	0	0	0	30	30	0	0	0	0
Environmental Monitoring Costs	0	0	0	2,100	2,100	0	0	0	0
Laundry Services	0	0	0	158	158	0	0	0	0
Small Tools and Minor Equipment	0	0	0	2	2	0	0	0	0
Chemical Decon/Deboration Energy	0	0	0	252	252	0	0	0	0
Plant Power Usage	0	0	0	2,376	2,376	0	0	0	0
Totals for PERIOD 2	3,260	115	170	15,212	18,757	471.17	9,921	504,391	6,122

	Costs ($ 000)					Waste Vol m^3	Crew Hours	Person-Hours	Person-mSv
Periods and D&D Activities	Decon	Remove	Package	Other	Total				
PERIOD 3: Spent Fuel Management (4 years)									
Utility Staff	0	0	0	9,242	9,242	0	0	599,040	4,037
DOC Staff	0	0	0	4,619	4,619	0	0	0	0
Regulatory Costs	0	0	0	40	40	0	0	0	0

Environmental Monitoring Costs	0	0	0	23	23	0	0	0	0
Laundry Services	0	0	0	187	187	0	0	0	0
Plant Power Usage	0	0	0	3,168	3,168	0	0	0	0
PERIOD 4: Dismantlement (5 years)									
Removal of NSSS	528	4,030	954	0	5,512	5,150.89	41,524	359,938	18,359
Removal of Contaminated Plant Systems	0	14,819	457	0	15,275	2,950.69	538,905	2,849,501	1,894
Decontamination of Site Buildings	1,139	635	345	0	2,119	661.8	25,233	93,067	430
Dry Active Waste	0	0	850	0	850	8,039.26	0	0	0
Termination Survey Costs	0	0	0	1,220	1,220	0	0	0	0
Utility Staff	0	0	0	12,167	12,167	0	0	748,800	2,982
DOC Staff	0	0	0	5,774	5,774	0	0	0	0
Regulatory Costs	0	0	0	50	50	0	0	0	0
Environmental Monitoring Costs	0	0	0	29	29	0	0	0	0
Laundry Services	0	0	0	1,266	1,266	0	0	0	0
Small Tools and Minor Equipment	0	0	0	401	401	0	0	0	0
Plant Power Usage	0	0	0	1,980	1,980	0	0	0	0
Totals for PERIOD 4	1,667	19,483	2,606	22,887	46,643	16,802.64	605,661	4,051307	23,665
GRAND TOTALS	4,927	19,599	2,776	64,476	91,778	17,273.80	615,582	5,154,737	33,824
GRAND TOTALS with 25%	6,158	24,498	3,470	80,595	114,722	17,273.80	769,478	6,443,421	33,824

Table 5. Decommissioning Costs for the SAFSTOR (II) Alternative

	Costs (SOOO)					Waste Vol m^3	Crew Hours	Person-Hours	Person-mSv
Periods and D&D Activities	Decon	Remove	Package	Other	Total				
PERIOD 1: Planning and Preparation (5 years)									
Utility Staff	0	0	0	1,287	1,287	0	0	0	0
DOC Staff	0	0	0	5,043	5,043	0	0	0	0
Special Tools and Equipment	0	0	0	2,768	2,768	0	0	0	0
Totals	0	0	0	9,097	9,097	0	0	0	0
Totals for PERIOD 1	0	0	0	9,097	9,097	0	0	0	0
PERIOD 2: Defuel and Deactivate (3 years)									
Removal of RPV Internals	0	115	155	0	270	195.64	2,465	22,183	1,052
Chemical Decontamination	2,365	0	0	0	2,365	130.26	3,520	21,120	457
Disposal of Concentrated Boron	895	0	1	0	896	13.59	3,936	11,808	120
Dry Active Waste	0	0	14	0	14	131.68	0	0	0
Utility Staff	0	0	0	6,830	6,830	0	0	449,280	4,493
DOC Staff	0	0	0	3,465	3,465	0	0	0	0
Regulatory Costs	0	0	0	30	30	0	0	0	0
Environmental Monitoring Costs	0	0	0	2,100	2,100	0	0	0	0
Laundry Services	0	0	0	158	158	0	0	0	0
Small Tools and Minor Equipment	0	0	0	2	2	0	0	0	0
Chemical Decon/Deboration Energy	0	0	0	252	252	0	0	0	0
Plant Power Usage	0	0	0	2,376	2,376	0	0	0	0
Totals for PERIOD 2	3,260	115	170	15,212	18,757	471.17	9,921	504,391	6,122
PERIOD 3: Spent Fuel Management (4 years)									
Utility Staff	0	0	0	9,242	9,242	0	0	599,040	4,037
DOC Staff	0	0	0	4,619	4,619	0	0	0	0
Regulatory Costs	0	0	0	40	40	0	0	0	0
Environmental Monitoring Costs	0	0	0	23	23	0	0	0	0
Laundry Services	0	0	0	187	187	0	0	0	0
Plant Power Usage	0	0	0	3,168	3,168	0	0	0	0
Totals for PERIOD 3	0	0	0	17,280	17,280	0	0	599,040	4,037

	Costs (SOOO)					Waste Vol m^3	Crew Hours	Person-Hours	Person-mSv
Periods and D&D Activities	Decon	Remove	Package	Other	Total				
PERIOD 4: Safe Storage (50 years)									
Spent Fuel Pool Water Treatment	134	0	86	0	220	28.6	1,800	10,800	50
Dry Active Waste	0	0	3	0	3	23.89	0	0	0
Utility Staff	0	0	0	31,694	31,694	0	0	936,000	3,728
DOC Staff	0	0	0	7,313	7,313	0	0	0	0
Regulatory Costs	0	0	0	500	500	0	o	0	0
Environmental Monitoring Costs	0	0	0	289	289	0	0	0	0
Laundry Services	0	0	0	296	296	0	0	0	0
Maintenance Allowance	0	0	0	724	724	0	0	0	0
Plant Power Usage	0	0	0	396	396	0	0	0	0
Totals for PERIOD 4	134	0	89	41,212	41,434	52.49	1,800	946,800	3,778
PERIOD 5: Dismantlement (5 years)									
Removal of NSSS	528	4,030	954	0	5,512	5,150.89	41,524	359,938	66
Removal of Contaminated Plant	0	14,819	457	0	15,275	2,950.69	538,905	2,849,501	3
Decontamination of Site Buildings	1,005	635	260	0	1,899	633.2	23,433	82,267	114
Dry Active Waste	0	0	847	0	847	8,015.37	0	0	0
Termination Survey Costs	0	0	0	1,220	1,220	0	0	0	0
Utility Staff	0	0	0	12,167	12,167	0	0	748,800	4
DOC Staff	0	0	0	5,774	5,774	0	0	0	0
Regulatory Costs	0	0	0	50	50	0	0	0	0
Environmental Monitoring Costs	0	0	0	29	29	0	0	0	0
Laundry Services	0	0	0	1,263	1,263	0	0	0	0
Small Tools and Minor Equipment	0	0	0	401	401	0	0	0	0
Plant Power Usage	0	0	0	1,980	1,980	0	0	0	0
Totals for PERIOD 5	1,533	19,483	2,518	22,884	46,417	16,750.14	603,861	4,040,507	187
GRAND TOTALS	4,927	19,599	2,776	105,684	132,986	17,273.80	615,582	6,090,737	14,124
GRAND TOTALS with 25%	6,158	24,498	3,470	132,106	166,232	17,273.80	769,478	7,613,421	14,124

Table 6. Projected Volumes of Radioactive Waste from the ANPP

Waste Category	Waste Code	Current Inventory (m^3)	Annual Generation (m^3)	Total Additional Generation Through	From D&D (m^3)	Total (m^3)
Solid - LLW	100	4,724	308	3,389	47,895	56,008
Combustible-Compactable	110	2,301	150	1,650	42,551	46,502
Combustible-NonCompactable	120	1,271	83	912	51	2,233
NonCombustible-Compactable	130	1,153	75	827	2,765	4,745
NonCombustible-Non-Compactable	140	---	---	---	1,143	1,143
Steam Generators & Low-Level Reactor Components	150	---	---	---	1,385	1,385
Solid - ML\V	200	1,144	1.5	17	805	1,966
Salt from DEF	210	783	27.0	297	---	1,080
Combustible-Compactable	220	236	1.0	11	---	246
Combustible-NonCompactable	230	81	0.3	4	---	85
NonCombustible-Compactable	240	29	0.1	1	146	176
Metal	250	15	0.1	1	660	675
Solid - High-Activity Wastes	300	28	0.3	3	237	267
Metal	310	26	0.3	3	---	29
Combustible-Compactable	320	1	0.0	0	---	2
NonCombustible-NonCompactable	340	---	---	---	34	34
Reactor Vessel Internals	350	---	---	---	203	203
Liquid Wastes	400	2,131	108	1,188	338	3,657
Total Volumes		8,027	418	4,596	49,275	61,898

Table 7. Waste Management Costs for Each D&D Alternative (thousands of constant year 2000 dollars)

Cost Category	Immediate DECON	Immediate ENTOMB	SAFSTOR-1 (DECON with 22 years Pool Operation)	SAFSTOR-2 (DECON with 4 years Pool Operation)	SAFSTOR/ ENTOMB-1 (22 years Pool Operation)	SAFSTOR/ ENTOMB-2 (4 years Pool Operations)
Solid LLW	13,608	3,075	15,003	13,982	2,957	2,884
Solid MLW	10,418	8,790	11,238	10,288	9,178	8,890
Solid HAW	6,418	4,023	1,690	1,690	3,573	3,573
Liquid waste	842	842	518	518	518	778
Subtotal	31,286	16,729	28,415	26,479	16,225	16,124
Contingency @25%	7,821	4,182	7,113	6,620	4,056	4,031
Total	39,107	20,912	35,563	33,098	20,282	20,155

Table 8. Waste Management Scenarios For Each Type Of Wastes

Type of Waste	DECON			SAFSTOR II		
	LLW	ILW	HLW	LLW	ILW	HLW
Solid – LLW/ILW	Dispose of waste in existing vault. Add new vault for D&D wastes.	Retrieve and treat as necessary and dispose in HICs in new LLW vault.		Store current wastes in existing storage (converted to disposal) facility. D&D wastes to new facility.	Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility.	
Combustible – Compactable	Compact future wastes in new press for 5X volume reduction.	Place in HICs in new LLW vault.	Place in NUHOMs canister and then in module.	Compact future wastes in new press for 5X volume reduction.	Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility.	Leave in place for SAFSTOR period. Then retrieve, package and place in New Disposal Facility.
Combustible – NonCompactable	Place directly into current vault.	Place in HICs in new LLW vault.		Store current wastes in existing storage (converted to disposal) facility. D&D wastes to new facility.	Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility.	
NonCombustible – Compactable	Compact future wastes in new press for 5X volume reduction. Then dispose in vaults.	Place in HICs in new LLW vault.		Compact future wastes in new press for 5X volume reduction. Then dispose in current and future vaults.	Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility.	
NonCombustible – NonCompactable	Place directly into current vault.		Place in NUHOMs canister and then in module.	Store current wastes in existing storage (converted to disposal) facility. D&D wastes to new facility.		Leave in place for SAFSTOR period. Then retrieve, package and place in New Disposal Facility.
Steam Generators & Low Level Reactor Components	Package in boxes or move as total unit to new LLW disposal vaults.			Package in boxes or move as total unit to new LLW disposal vaults.		
Salt from DEF		Place in HICs in new LLW vault.			Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility.	
Metal		Place in HICs in new LLW vault.	Retrieve, canisterize, dry, place in NUHOMs.		Leave in existing storage for Safstor period then retrieve, repackage in HICs, and emplace in new disposal facility	Leave in place for SAFSTOR period. Then retrieve, package and place in New Disposal Facility.
Solid-High-Activity Wastes			Retrieve waste and store in NUHOMs modules.			Leave in place for SAFSTOR period. Then retrieve, package and place in New Disposal Facility.
Reactor Internals			Cut up as necessary to place in NUHOMs then in module.			Leave in place for SAFSTOR period. Then retrieve, package and place in New Disposal Facility.

Table 9. Summary of ANPP Spent Fuel Management Costs

Option	Projected Shutdown Date	Capital Cost ($ millions)	Operating Cost ($ millions)	
			Annual	50- Year Total
Combination of Wet and Dry	Not Applicable	5.9	4.2	209
Expansion of Existing On-Site Dry Storage Facility	2004	25.5	0.22	11.0
	2009	33.7	0.22	11.0
New Off-Site Dry Storage Facility	2004	39.9	0.22	11.0
	2009	49.1	0.22	11.0
Interim Storage by Another Country	2004	90-180		
	2009	115-225		
Permanent Disposition by Another Country	2004	350-580		
	2009	450-750		

TABLE 10. The comparative data of the PNNL and SOGIN estimates.

	Phase	Cost		Duration [Years]		Manpower [Man- months]		Doses [Man-Sv]	
		SOGIN [MECU]	PNNL [US $]	SOGIN	PNNL	SOGIN	PNNL	SOGIN	PNNL
1	Post operation and preparation of Unit 1	17.9	11	3	5	13,820	0	1.7	0
2	Plant preparation for SAFSTORE	87.7	45	9	7	28,000	8,620	1.6	10.2
3	Safe storage period	69.0	52	35	50	36,530	7,400	0.26	3.8
4	NPP dismantling and site release	273.2	116	14	5	37,085	31,560	4.6	0.2
5	Site restoration	36.3		5		8,570		0	
6	Total	481.1	224	66	67	124,005	47,582	8.16	14.2

Annex 2

BULGARIA

1. Introduction

At present there is one NPP in Bulgaria with six WWER reactors (four WWER-440 Model V230s and two WWER-1000 Model V320s). The six units have a total capacity of 3,760 MW(e), generating about 45 % of the country's electricity production.

The first two units at the Kozloduy NPP were put in operation in 1974 and 1975. The final shutdown of these units is planned in 2005 and 2006, after expiration of their design lifetime. Following the Understanding of 29.11.1999 between the European Commission (EC) and the Bulgarian Government Units 1 and 2 should be definitively shutdown before the year 2003.

2. Legislative Aspects (Situation at the beginning of 2001)

The most important legislation regulating nuclear activities in Bulgaria is the Act on the Use of Atomic Energy for Peaceful Purposes. The primary legislation for nuclear safety was enacted in 1985, and amended in 1995. The main nuclear act is currently under review.

In accordance with the Atomic Act, the licensee (the operator of facility) is responsible for the implementation of decommissioning.

From the beginning of the year 2001 a new "Regulation on Safety on NPP during Decommissioning" has been published. It is the basis for a national licensing system for the decommissioning of NPPs.

3. Financial Aspects

The Act on the Use of Atomic Energy requires the establishment of a special decommissioning fund, which was done in the beginning of 1999. The Kozloduy NPP pays a special fee to this fund. This means that during normal operation of units 1 and 2, yearly approximately 11 million USD are deposited. Earlier shutdown of units leads to losses for the decommissioning fund.

Considering the financial implications of early closures, the EC offered a multi-annual assistance package for the Bulgarian energy sector as referred to in the document of Understanding. The package includes grants of 200 MEUR over the period 2000-2006, the provision of the second half of this sum to be confirmed in the year 2002, depending on confirmation of the Understanding on the definitive closure dates for units 3 and 4.

Following the Understanding of 29.11.1999 the Commission took the initiative to establish an International Decommissioning Support Fund under the management of the European Bank for Reconstruction and Development (EBRD), through which it intends to channel the bulk of its grant assistance. The Board of the Bank established this Fund in June 2000.

4. Technical Assistance

Based on the Understanding of 29.11.1999 two documents were developed:

a) A Strategic Plan for the implementation of the Understanding of 29.11.1999;

b) A Working Plan for the preparation of the final shutdown of units 1 and 2.

The Working Plan was accepted by the EC and will be used as a "road map", including a timetable, for the implementation of the preparatory activities directly linked to the definitive closure and decommissioning of units 1 and 2. It will be used in the context of the planning of projects to be supported through the grant element of the assistance package under the 29.11.1999 Understanding.

The main specific activities that are foreseen in order to prepare the units 1 and 2 for the final shutdown are:

a) Development of a detailed technical project ready for implementation on-site after the final shutdown of units 1 and 2;

b) Preparation of the site;

c) Procurement of equipment;

d) Commissioning of the Waste Processing Plant and Storage Facility;

e) Processing of waste from operations of the units;

f) Design and construction of the dry intermediate storage for spent fuel;

g) Optimisation of the last refuelling.

Annex 3

CZECH REPUBLIC

1. Responsibilities

In the Czech Republic the principles of radioactive waste management and funding of the back end of the fuel cycle are clearly specified in the Act No. 18/1997 Coll. (the Atomic Act [3-1]). These principles have already been implemented in practice.

Under this act, the producer of radioactive waste bears all costs associated with its management, from generation to disposal, including monitoring of radioactive waste repositories after their closure and including the necessary research and development activities.

The Atomic Act enacts that the state guarantees the safe disposal of all radioactive wastes. For ensuring this obligation a state organisation was set up in 1997 - it is called RAdioactive Waste Repositories Authority (RAWRA). This organisation is responsible for activities related to disposal of radioactive wastes in the Czech Republic and it also ensures sufficient disposal capacities in advance. As far as decommissioning is concerned RAWRA also verifies cost estimates and monitors reserves of licensees for decommissioning of their installations.

2. Financing of Decommissioning of Nuclear Installations

According to the Czech legislative provision the operator of a nuclear installation (nuclear power plant, interim spent fuel storage facility) has to gradually create a financial reserve for decommissioning of the referred nuclear installation so that financial resources are available for preparation and implementation of decommissioning at the required time and in the required amount, in accordance with the decommissioning strategy approved by the regulatory body. The reserve for decommissioning accounts to the expense for achieving, ensuring and maintenance of income.

The reserve for decommissioning is intended to cover the costs of decommissioning activities defined by the regulation No. 196/1999 [3-2]. Decommissioning activities are defined as activities performed in the process of decommissioning, especially decontamination, dismantling, demolition, processing of radioactive wastes arising during decommissioning, their transport to the repository, operation and maintenance of technological systems which are used for protective separation/deposition in the case of selecting the concept of safe enclosure.

3. Financing of Activities Connected with the Disposal of Radioactive Waste

A producer of radioactive wastes is obliged to deliver financial means to a nuclear account for covering the costs related with the disposal of all radioactive wastes, i.e. spent fuel, waste from the operation of nuclear facilities and wastes which originate during decommissioning of nuclear facilities.

The financial means are delivered to a nuclear account in the form of deliveries. The nuclear account is opened at the Czech National Bank and is administered by the Ministry of Finance. The nuclear account is a part of the accounts of state financial liabilities and assets. A decision about use of the means from the nuclear account is made by the government of the Czech Republic on the basis of the approved plan of activities and budget of RAWRA.

The amount of delivery to the nuclear account was provided for by the order of the government No. 224/1997 Coll. and it is CZK 50 from each MWh generated in the nuclear power plants.

4. Cost of the Radioactive Waste Disposal

A repository for radioactive waste is in operation and the conditioned radioactive waste from the Dukovany NPP is disposed there. This repository is located in the territory of the Dukovany NPP. The construction of the repository took place in 1987-1994. Trial operation was completed in 1995.

Based on the current estimates the capacity of this repository is sufficient for the operational radioactive waste from both the Dukovany and the Temelín NPPs as well as for waste produced by the decommissioning of Dukovany NPP and Temelín NPP. Construction of more disposal capacities is not envisaged.

Wastes from operation and decommissioning of nuclear power plants which do not fulfil the criteria of Limits and Conditions for the disposal in the repository as they exceed the limits permitted for given radionuclide (i.e., ^{63}Ni) are, according to the concept of decommissioning of nuclear facilities in CEZ, planned to be deposited in a deep geological repository.

Costs of disposal of both categories of wastes are financed from the nuclear account.

5. Financing of Spent Fuel Storage

Spent fuel originating from operation of the Dukovany NPP is stored in an interim spent fuel storage facility which is located inside the NPP territory. The capacity of the interim storage facility is 600 t of heavy metal (U). With present calculation of spent fuel production the capacity of the interim storage facility will be drawn in 2006. For these reasons a new storage capacity is being prepared for the production of spent fuel from the Dukovany NPP.

Spent fuel storage is financed by CEZ on an ongoing basis and is not included in the nuclear power plant decommissioning costs. Expenditures for construction of storage facilities are not included in the power plant decommissioning costs either.

6. Actualisation of Cost Estimates for Decommissioning

Requirements concerning regular update of cost estimation for decommissioning are set in the regulation No. 196/1999 Coll. In compliance with this regulation an update of the cost estimate has to be made at least once every five years.

7. Methodology of Cost Estimation for Decommissioning

The estimate of expenses for decommissioning has to be set up as a sum of costs for individual decommissioning activities considered for a given decommissioning method and assumed time schedule of decommissioning. Expenses for individual decommissioning activities shall be expressed in standard prices of the year in which the estimate is performed. The estimate of expenses in the cases, where it is possible, is processed in a form of products of the number of considered specific units and the price of each specific unit.

8. Cost Estimate Related to the Dukovany NPP Decommissioning

The decommissioning costs for the Dukovany NPP were taken over from the decommissioning study of the Dukovany NPP [3-3]. The cost estimate is relevant to the decommissioning strategy accepted by the utility and approved by the regulatory body - the State Office for Nuclear Safety (SONS).

The estimated decommissioning costs for the adopted strategy - safe enclosure of active objects for 50 years - are 12,520 million CZK (419.4 million USD, as of 31 December 1998). Decommissioning costs are relevant to the 4 units of the Dukovany NPP.

9. Decommissioning Plan

Preparation for decommissioning of nuclear power plants, operated by CEZ, is solved in compliance with requirements of the Atomic Act within the range and at a level required by this act.

The decommissioning study entitled “Study for Decommissioning of the NPP Dukovany” was approved by the SÚJB from the point of view of the Atomic Act requirements in 1998. A conceptual plan for decommissioning defined by the Atomic Act as a decommissioning method proposal was elaborated in the study. A decommissioning cost estimate applicable to the proposed relevant decommissioning method was verified and approved by the RAWRA in 1997. The financial reserve for decommissioning of the Dukovany NPP is created in compliance with the Atomic Act from 01.07.1997.

Based on the decision of the SONS the next upgrade of the conceptual plan for decommissioning of the Dukovany NPP will be elaborated and submitted for approval in 2003. Actualisation of cost estimates will be prepared and submitted for verification by the RAWRA in 2003.

The Temelín NPP decommissioning study for issuing a license for the first loading of nuclear fuel into the reactor was completed and submitted for approval to the SONS. A proposal for a decommissioning method for the Temelín NPP was approved by the SONS in 1999. The cost estimate for decommissioning, relevant to the proposed decommissioning method, was verified by the RAWRA in 1999.

REFERENCES

[3-1] ACT No. 18/1997 Coll., on Peaceful Utilisation of Nuclear Energy and Ionising Radiation (the Atomic Act) and on Amendment and Additions to Related Acts.

[3-2] REGULATION No. 196/1999 Coll., on the Decommissioning of Nuclear Installations or Workplaces with Significant and Very Significant Ionising Radiation Sources.

[3-3] EGP INVEST UHERSKÝ BROD, Co. Ltd.: Study for Decommissioning of the NPP Dukovany, 1998.

Annex 4

FINLAND

Abstract

Fortum Power and Heat Ltd. has revised the decommissioning plan for the Loviisa Nuclear Power Plant (Loviisa 1 and Loviisa 2) at the end of the year 1998 [4-1]. The plan is based on immediate dismantlement after shutdown of the power plant. Experienced plant personnel will still be available to lead the decommissioning work. Only the radioactive plant systems, components and structures will be dismantled and disposed of.

The electric power of the power plant has been increased to 2 x 510 MW(e) in 1998, and the lifetime is planned to be extended to 45 years in the decommissioning plan.

The decommissioning of the power plant is planned to begin in 2022 and will be finished in 2048. The reason for this long time is that the spent fuel will be stored at the plant for 20 years after shutdown of the power plant. Later, the spent fuel wil be transported from the site to the encapsulation plant, and to final disposal.

The large and heavy reactor components, e.g., pressure vessels and steam generators, will be disposed of as such, without cutting into smaller parts. This will save time and radiation doses. These large components will be used as packagings (barriers) for smaller equipment. Decommissioning wastes will be disposed in the underground repository situated at the site at a depth of about 110 m. This repository is already used for wastes from the power plant, and it will be enlarged to accommodate the wastes from decommissioning as well.

The total volume of decommissioning wastes is 14,800 m^3, when packaged in boxes. The manpower needed for the decommissioning operations is about 2,800 man.years. The collective radiation dose for personnel is estimated to be about 9.2 man.Sv. The cost estimate for the decommissioning is about 1,117 million FIM or 220 million USD (disposal of decommissioning wastes included).

1. General

The Loviisa NPP consists of two WWER-440 type PWR units. The first unit (Loviisa 1) was taken into commercial operation in 5/1977 and the second (Loviisa 2) in 1/1981. Each unit has operated well with high availability, high load factors and low personnel doses. The Loviisa NPP is owned and operated by Fortum Power and Heat Ltd. The electric power of the power plant has been increased to 2 x 510 MW(e) in 1998, and the life time is planned to be extended to 45 years.

The principal legislation regulating nuclear activities in Finland is the Nuclear Energy Act and Decree of 1988. They define the responsibilities and the principles for financing decommissioning projects. The licensing procedures for decommissioning are not yet defined in detail.

The licensees (e.g., utilities) are responsible for the implementation of decommissioning (and they are also responsible for the management and disposal of all types of waste: spent fuel, operational and decommissioning wastes). In the event that the licensee is incapable of doing so, the state has the secondary responsibility. In this case, the costs are covered by assets collected beforehand in the Nuclear Waste Management Fund and by securities provided by the licensee.

According to a governmental policy decision of 1983, the licensees are obliged to update their decommissioning plans every five years. These plans aim at ensuring that decommissioning can be appropriately performed when needed and that the estimates for decommissioning costs are realistic. The latest updates of decommissioning plans were published at the end of 1998 [4-1], and the earlier plans were published in 1982, 1987 and 1993.

In the past, spent fuel from the Loviisa NPP was transported to the former Soviet Union/Russian Federation with no return of reprocessing wastes. However, plans for spent fuel management have been revised based on the amendment to the Nuclear Energy Act prohibiting the export of spent fuel beyond 1996.

2. Bases of Decommissioning

The plan is based on immediate dismantlement after shutdown of the power plant. The reactors are decommissioned after 2 years of cooling time. Experienced plant personnel will still be available to lead the decommissioning work. The decommissioning of the NPP is planned to begin in 2022. The spent fuel will be stored at the plant for 20 years after shutdown of the power plant. After that the spent fuel will be transported from the site to the encapsulation plant, and to final disposal. The decommissioning of the NPP will be finished in 2048.

The plan covers dismantling of only those structures, systems and components that exceed the clearance constraints; thus the "green field" option is not required on the basis of the nuclear legislation. The site can be reused, e.g., for power production.

After shutdown of the power plant, the spent fuel storage and waste solidification plant are still operated, and operation and decommissioning of these are taken into account in the decommissioning plan.

The large and heavy reactor components, e.g., pressure vessels and steam generators, will be removed intact without cutting in pieces. This will save time and radiation doses. These large components are used as packagings (barriers) for smaller equipment.

The decommissioning technique is based on the present technology. The radiation doses are optimised in all essential decommissioning works (ALARA principle).

The decommissioning wastes will be disposed in the underground repository situated at the site at a depth of about 110 m. This repository is already used for wastes from the power plant, and it will be enlarged to accommodate the wastes from decommissioning as well. The operation and sealing (closure) of the repository are taken into account in the decommissioning plan.

Two clearance options, unconditional and conditional, are defined. The following activity constraints are applicable to *unconditional clearance:*

- The total activity concentration, averaged over a maximum amount of 1,000 kg of waste, shall not exceed 1 kBq/kg of beta or gamma activity or 100 Bq/kg of alpha activity. In addition, no single item or waste package weighing less than 100 kg may contain more than 100 kBq of beta and gamma activity or 10 kBq of alpha activity.
- The contamination of non-fixed radioactive substances on accessible surfaces, averaged over a maximum area of 0.1 m^2, shall not exceed 4 kBq/m^2 of beta and gamma activity or 400 Bq/m^2 of alpha activity.

For *conditional clearance*, activity constraints based on a case-by-case approval by the authority STUK are applied which, however, shall remain below those included in the Nuclear Energy Decree, i.e.:

- The average activity concentration in the waste shall be less than 10 kBq/kg;
- The total activity of cleared waste received by a transferee in one year shall be less than 1 GBq; and
- The total alpha activity shall be less than 10 MBq.

Experiences indicate that monitoring of dismantled equipment for clearance is a demanding task from both implementor's and regulator's point of view.

3. Preparatory Phase of Decommissioning

After shutdown of the power plant, there will be a short (2 years) preparatory phase of decommissioning before actual dismantling work begins. During this preparatory phase, e.g., the following works are carried out:

- Unsealing of the reactor, defuelling;
- Transfer of spent fuel from the ponds in the reactor building to the spent fuel storage ponds;
- Transfer of dummy fuel assemblies (fuel element-like steel components replacing the outermost layer of fuel assemblies in the core in order to decrease neutron embrittlement of the reactor pressure vessel) and control rod absorbers to fuel storage ponds;
- Flushing of process systems associated with the primary circuit;
- Decontamination of the primary circuit;
- Treatment and conditioning of liquid/wet wastes;
- Building of hauling openings for transfer of large equipment, and building of a driving ramp to the reactor building segment area;
- Purchase of special equipment needed in the decommissioning work.

There are no special problems in most of these operations, because they are directly based on normal outage operations.

4. Dismantling Works and Radioactive Waste Management

During power operation of a NPP, activation of different materials takes place due to the neutron irradiation caused by the nuclear fuel inside the reactor pressure vessel. In addition, contamination of surfaces takes place due to activated corrosion products transported by the primary circuit water.

4.1. Activated Material

When the reactor is in operation, the reactor pressure vessel (RPV), the interior parts of the reactor, thermal insulation sheets of the reactor pit and the reactor biological shield are activated by neutron irradiation.

Dismantling of the activated material (equipment, systems, structures) is the most demanding task of all decommissioning activities.

Detachment of reactor starts after dismantling of the primary coolant circuit piping. All structures are detached above the reactor support level, the pipes are cut, the support fixing is dismounted and, finally, the RPV is lifted from the shaft with a remote-controlled crane. After this, the RPV is covered by a radiation shield, turned into a horizontal position and moved onto the transport carriage in the segment area. On the carriage (capacity 326 metric tons), the RPV is transported out of the reactor building and moved directly into the repository at -110 m level. The transport distance to the repository within the site is more than 1 kilometre, and it is mainly in an access tunnel. In the repository, the RPV is turned in upright position and lifted directly into a prefabricated silo. The reactor internals and all dummy fuel assemblies (steel elements to attenuate the neutron flux to the RPV) are put inside the RPV in the silo.

Finally the RPV is closed with the original reactor head and fully filled with concrete. In the repository, the RPV composes a barrier preventing and slowing down the spreading of radioactive materials. Figure 1 presents the reactor silo at the moment of closing the space. All large contaminated components of the primary coolant circuit will be put intact in the hall above the reactor silo.

Reactor internals will be transported with the steel shielding cylinder, that is used at the NPP refuellings for removing the reactor internals.

Besides the challenging decommissioning measures of the RPV and inner components, the most time-consuming and complicated measure is the dismantling of the reactor biological shield up to below the clearance level. During the NPP operation, the thermal insulation sheets and the biological shield of the reactor pit are activated, as well as the structural concrete behind the shield. Dismantling of the above-mentioned constructions requires special radiation protection and remotely controlled treatment. It is possible to bore and saw all structures remotely controlled by means of the dismantling equipment both under water and dry. The control equipment is located on the main floor of the reactor building. The estimated dismantling depth at the reactor core zone is about 1,200 mm, and the weight of the material to be dismantled is 765 metric tons in total. This dismantling is very labour intensive, estimated to take about 18 months, and therefore even quite low dose rates can cause significant total doses to the operators. Activated material, which has been cut into smaller parts, will be packaged in different types of concrete and wooden boxes.

Weights and volumes of activated waste:

Equipment/Structure	Weight/metric tons excl. packages	Volume/m^3 packed
Reactor pressure vessels, internals, dummy fuel assemblies	956	1,484
Control rod absorbers and intermediate rods	81	651
Thermal insulation plates and biological shields	1,230	1,980
Total	2,270	4,120

Activity inventory of activated waste:

Equipment/Structure	Total activity/TBq
Reactor pressure vessels	1,060
Reactor internals	52,000
Dummy fuel assemblies	184,000
Control rod absorbers and intermediate rods	2,400
Thermal insulation plates and biological shields	14
Total	240,000

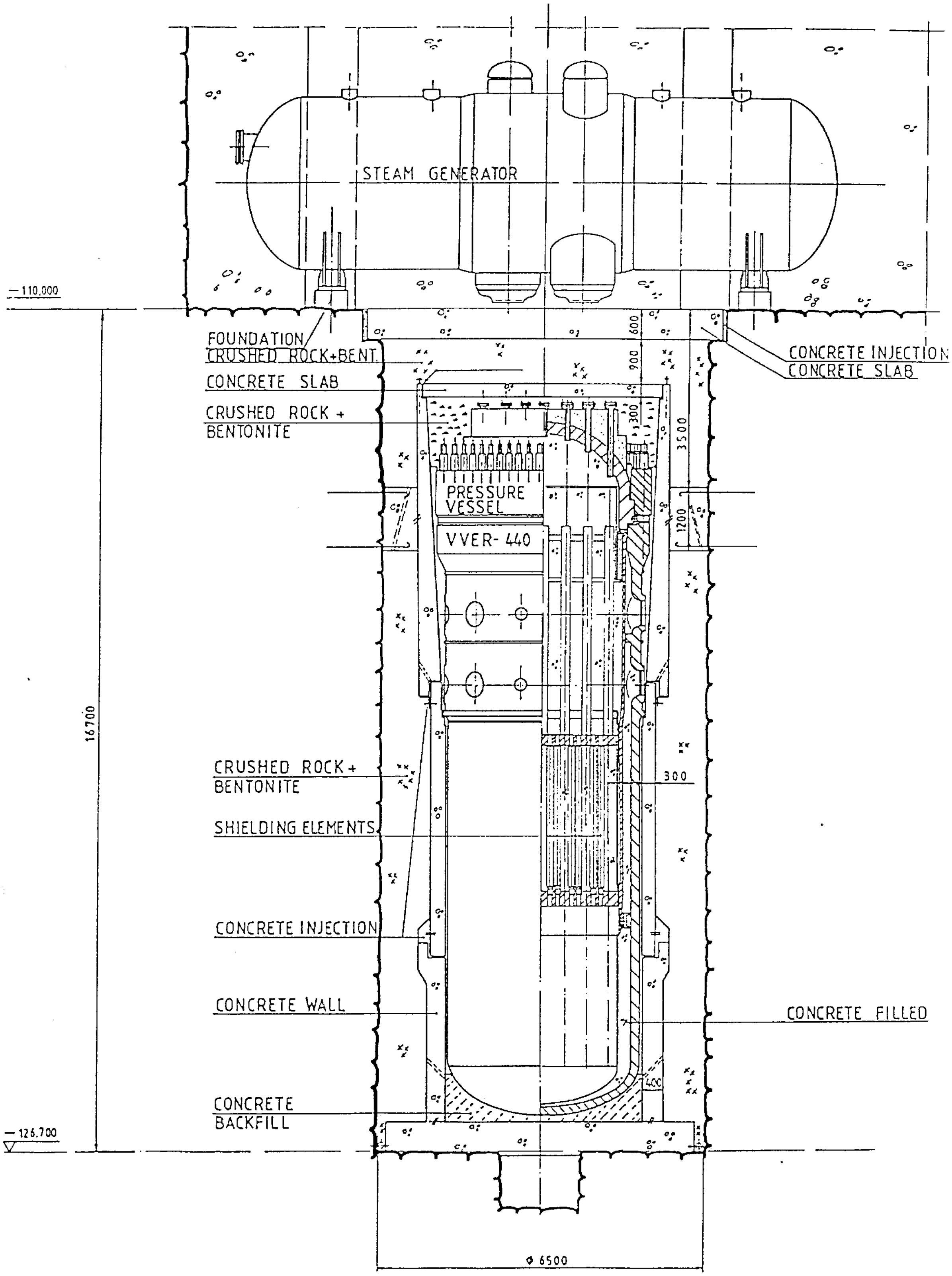


Figure 1. Closed reactor silo.

The total activity of the activated decommissioning waste is about 99 % of the total activity of all decommissioning waste. Most of the activity results from the Fe^{55} radionuclide. It is, however, short-lived and a week emitter of beta radiation (half-life 2.7 years). It has, therefore, insignificant effect on the radiation safety of decommissioning. The most important nuclide for radiation safety during decommissioning is Co^{60}. For the long term safety of a repository the nuclides C^{14}, Ni^{59} and Mo^{93} are most important.

4.2. Contaminated Material

In the decommissioning plan, the contaminated material is divided in two classes. The surface dose rate of class 1 material is $\geq$ 0.10 mSv/h and that of class 2 is < 0.10 mSv/h. The contaminated material is divided in classes on the basis of the radiation level measurements performed at the Loviisa NPP. The systems and constructions to be dismantled were defined and estimated on the basis of the measurements. The systems and constructions were evaluated in accordance with detailed as-built drawings.

The RPV heads, control rod drive units, steam generators, pressurisers and bubblers, primary coolant circuits and certain auxiliary systems in the reactor buildings are considered to belong to contamination class 1. Moreover, there are contaminated systems of class 1 in the auxiliary buildings and in the liquid waste storage.

Systems belonging to contamination class 2 are also situated in the reactor buildings, auxiliary buildings, laboratory building, and in the liquid waste storage. Even systems that are estimated to be contaminated in future are included in the overview.

All large contaminated components like steam generators, pressurizers, bubblers, deaerators, evaporators, ion exchangers, etc., are dismounted and transported into the repository. Some other wastes (valves, pipe pieces, etc.) are packaged into these large components in the repository. Under these circumstances, the large components are used as waste packages and compose an engineered barrier in the repository. All other equipment and pipings are dismantled in entities with suitable length. They are transported to a cutting and packaging station and put into suitable concrete or wooden packages (containers). Finished packages are closed and transported inside radiation shields into the repository. Totally 770 concrete and 464 wooden containers will be needed.

Weights and volumes of contaminated waste:

Equipment/Structure	Weight/metric tons excl. packages	Volume/m^3 packed
Reactor buildings		
Process systems	3,692	4,532
Structures	240	248
Auxiliary buildings		
Process systems	946	2,437
Structures	54	74
Fuel storage 1 and 2		
Structures	559	871
Waste buildings J1&J2		
Process systems	148	417
Structures	22	29
Laboratory building		
Structures	3	3
Total	5,670	8,620

It is estimated that the total activity of the contaminated decommissioning waste will be 32 TBq. The most important radionuclide is Co^{60}. Contaminated waste accounts for about 1 % of the total activity of the decommissioning waste.

Decommissioning entails operations that result in maintenance waste just as during power plant operation. The maintenance waste accumulating during decommissioning will be packed in 200 litre steel drums, and wet wastes are solidified in concrete drums (inside volume 1 m^3). The estimated total volume of waste is 2,020 m^3. The activity of this waste is insignificant compared to that of other decommissioning waste.

5. Personnel Doses

It is a general radiological protection requirement that exemption of wastes from a NPP shall be kept as low as reasonably achievable and not give rise to radiation exposure of the public or the workers at the waste treatment facility exceeding:

- An effective dose of 0.01 mSv/a to the most exposed individuals (members of the so called critical group); or
- The workers' annual individual dose limit of 20 mSv.

When planning the decommissioning activities, special attention has been paid to radiological safety. Dose rates have been determined for each decommissioning phase. Dose rates have been utilised in dimensioning and taking technical decisions. Working times of each decommissioning phase have been estimated. Dose rate calculations were based on the new activity inventory in waste, electric power increase, extended lifetime, and on the radiation levels measured at the Loviisa NPP. Doses during decommissioning activities are caused mainly by the radionuclide Co^{60}.

Estimated radiation doses in decommissioning, man Sv:

Preparatory phase (excl. decontamination)	0.66
Decontamination of primary circuit	0.03
Dismantling works	
- Activated material	2.66
- Contaminated material in reactor buildings	2.20
- Other contaminated material	0.45
Plant personnel	2.40
Provision for unspecified work, 10%	0.80
Total	9.20

6. Time schedule and Manpower Demand

The service life of the Loviisa NPP is estimated to be 45 years. Decommissioning of Loviisa 1 should therefore start in 2022. The spent fuel will be stored at the plant for 20 years after shutdown of the power plant. After shutdown of the power plant, the spent fuel storage, waste solidification plant and waste repository are still operated, and operation and decommissioning of these facilities (and sealing of the repository) are taken into account in the decommissioning plan.

The whole decommissioning phase, from the start of Loviisa 1 up to sealing of the waste repository in 2048, and expiration of licence obligations, will take about 27 years.

Time schedule for the decommissioning of the Loviisa NPP:

	Years													
	2022	2023	2024	2025	2026	2027	2028	2029	2030		2045	2046	2047	2048
Operation														
Loviisa 1	■													
Loviisa 2	■	■	■	■										
Storing of spent fuel	■	■	■	■	■	■	■	■	■		■			
Preparatory phase	■	■	■	■	■	■								
Decommissioning														
Activated material			■	■	■	■	■	■						
Contaminated material			■	■	■	■	■	■						
Spent fuel racks											■	■		
Final repository														
Disposal of wastes	■	■	■	■	■	■	■	■	■		■	■	■	
Sealing of repository														■

The amount of work for preparation of decommissioning and for decommissioning itself comprises the sum of the work done by Fortum's permanent staff and by the decommissioning subcontractors. It is assumed that when the decommissioning phase starts, the operational organisation at the Loviisa NPP will change to a decommissioning organisation, that will have various subcontractors that will execute the dismantling works based on the plans.

Relating to the removal of activated and contaminated material, the required number of personnel was calculated and the duration of the dismantling phase. In this way the necessary manpower for the various decommissioning activities was defined. It was estimated that the number of personnel for Fortum's decommissioning organisation should be 135 persons. During the preparatory phase, the staff number will be higher (156), but at the end of the decommissioning phase it will be lower than that, respectively. The number of personnel from the decommissioning subcontractors varies in time, but will be 280 persons at the maximum. The total personnel number on site amounts to almost 400 at the maximum. Three peaks can be distinguished in the labour requirements: at the beginning of the preparatory phase for the decommissioning of the Loviisa 2 unit, at the start of the actual decommissioning of the Loviisa 2 unit and at the dismantling of the contaminated auxiliary systems after spent fuel was removed from the NPP.

Dismantling works are estimated to be carried out 7 hours/day (from the year 2022 on) with an efficiency of 78 %. Working days in a month are estimated to be 22 at the maximum.

Manpower demand in various years:

Years after Loviisa 1 shutdown	Fortum permanent staff, man years	Subcontractor staff, man years
1	156	29
2	156	33
3	135	87
4	297	82
5	297	101
6	141	87
7	141	135
8	71	45
24	71	280
25	71	242
26	71	39
Totally	1,607	1,160

In decommissioning, project management, planning and operational tasks are taken care of by Fortum's staff as much as possible.

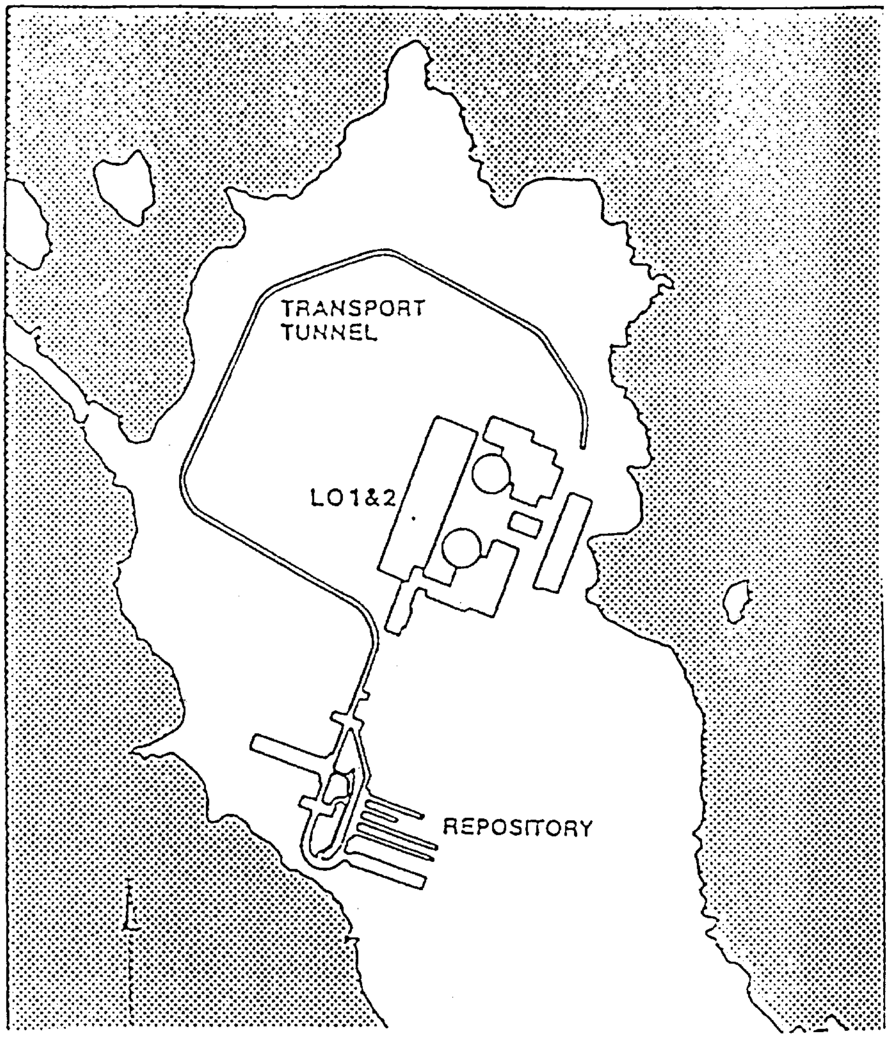
Manpower demand in various tasks:

	Task	Fortum permanent staff, man years	Subcontractor staff, man years
1	Preparatory phase	624	66
2	Activated material		
	- Reactor pressure vessels		13
	- Reactor internals, dummy fuel assemblies		12
	- Control rod absorbers		7
	- Reactor dry silos		3
	- Thermal insulation plates and biological shields		64
3	Contaminated material		
	- Reactor buildings		426
	- Auxiliary buildings, fuel storage, waste buildings, laboratory building		569
4	Operation of decommissioning phase	938	
5	Surveillance	45	
Totally		1,607	1,160

The total manpower demand in decommissioning of Loviisa NPP is about 2,800 man years.

7. Disposal of Decommissioning Waste and Safety Analyses

A decommissioning waste repository will be associated with the operating waste repository (already used as a repository from 1998) at the Loviisa NPP. The repositories were organised south-west from the NPP units, at a distance of about 400 m, under the ground at level –126 to -92 m. An access tunnel runs from the surface to the repositories; a heavy transport equipment of 326 metric tons can drive along it. Figure 2 presents the location and the form of the areas for power plant wastes and for decommissioning wastes.



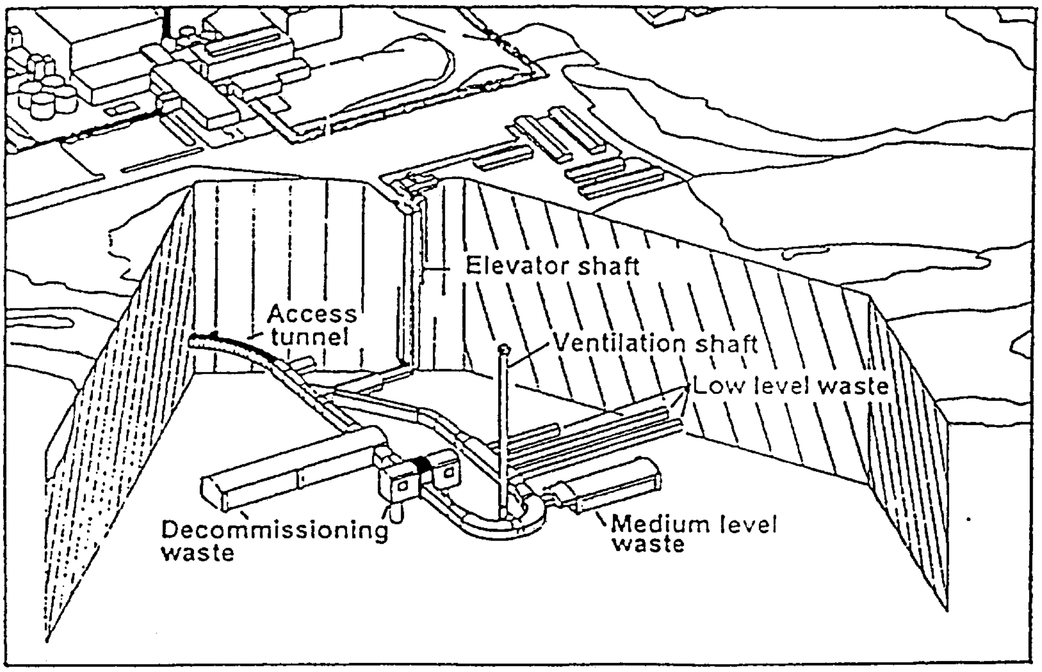


Fig. 2. Repository for decommissioning waste from Loviisa NPP

The positioning of the repositories in the bedrock is based on thorough rock research works carried out on the Hästholmen island of the Loviisa NPP. On grounds of stress state measurements, the repositories were placed parallel with the greatest main stress field. Two planes of weakness with a height of about 20 m are going in the bedrock of the area. The repositories were placed such that the protective distance to the water-conducting planes of weakness is sufficient. The most active decommissioning material (reactor pressure vessel with internals, etc.) was placed in the soundest part of the rock on the disposal site.

The transport distance to the repository within the site is more than 1 kilometre, and it is mainly in an access tunnel. In the repository, the RPV is turned in upright position and lifted directly into a prefabricated silo. The reactor internals and all dummy fuel assemblies are put inside the RPV in the silo. Finally the RPV is closed with the original reactor head and fully filled with concrete. In the repository, the RPV composes a barrier preventing and slowing down the spreading of radioactive materials. Figure 1 presents the reactor silo at the moment of closing the space. All large contaminated components of the primary coolant circuit are located intact in the hall above the reactor silo. The steam generators will be piled on the reactor in two rows and in piles of three. The rock cavern is equipped with a bridge crane to facilitate component arrangement in the cavern.

The rest of the activated and contaminated components and materials will be put into a separate rock cavern. The total cavern volume for all decommissioning waste will be 44,660 m^3.

On-site disposal of the decommissioning waste involves significant benefits in comparison with off-site disposal. Conditioning and packaging of waste for disposal becomes easier because the waste packages need not meet the transport requirements concerning, e.g., external dose rate and surface contamination. It is even possible to remove and dispose of large components as such, without a need for cutting. Considerable cost savings and some reduction in occupational doses can be achieved in this way. Cost savings are also achieved as a result of the very short transport distance.

The decommissioning waste disposal plan includes fairly comprehensive safety assessment: performance assessment for the Loviisa NPP decommissioning waste repository. Due to the similarity of the design and the system of barriers, the same methodology as in the respective assessment for the repository already in operation was applied. The long-lived activity in decommissioning waste is about two orders of magnitude higher than that of the operational low and intermediate level waste. However, the radiotoxicity of dominating nuclides in decommissioning wastes, such as Ni^{63}, are low in comparison with those of the dominating nuclides in operational waste. In addition, most of the activity in decommissioning waste is incorporated in massive metal components which corrode very slowly in the alkaline conditions that prevail in the repository. Consequently, the assessment indicates that the same safety level as for disposal of operational waste can be achieved. The expected individual doses remain below the constraint of 0.1 mSv/a and the cumulative collective dose over 10,000 years is not more than about 1 man Sv.

8. Cost Estimate

The costs for the decommissioning of the Loviisa NPP were calculated based on plans and the estimated amount of work at the price level of December 1998. For the cost estimate the knowledge of prices available at different departments of Fortum were utilised, as well as budget offers received from various suppliers. Budget offers were especially asked for equipment and machines for which Fortum had no previous experience. When preparing the cost estimate it was assumed that project management, planning and operational tasks are taken care of by Fortum's staff as much as possible. For estimating the personnel costs the unit costs of Fortum's organisation were used, and for the subcontractors, unit prices based on tenders, wage statistics, etc. Manpower unit costs are very important because decommissioning work is dominated by human work, expressed in man.years. As an example, the costs for a plant manager, engineer and technician are about 640,000, 430,000 and 305,000 FIM/a correspondingly.

Estimated decommissioning costs (December 1998):

	Object	MFIM
1	Project administration and planning (Fortum´s manpower 14.7 MFIM)	20.2
2	Preparatory phase (Fortum´s manpower 128.6 MFIM)	160.0
3	Activated material (thermal insulation plates and biological shields 36.3 MFIM)	56.0
4	Contaminated material (reactor buildings 182.4 MFIM, other buildings 235.5 MFIM)	417.9
5	Maintenance waste	5.8
6	Waste packages	17.6
7	Repository (44 660 m^3)	66.3
8	Operational cost in the decommissioning phase (Fortum´s manpower 209.5 MFIM)	271.7
9	Provision for unspecified costs 10 %	101.5
Total		1,117.0

The total sum is about 220 million USD (USD = 5.09 FIM in December 1998).

9. Conclusions

Key ideas in our decommissioning plan are the following: decommissioning waste management is integrated within the operational waste management. Repositories are licenced in good time. The reactor pressure vessel will be removed intact into the repository and the reactor pressure vessel will be used as a waste package for the reactor internals. Other large components (steam generators, pressurizers, bubblers, deaerators, evaporators, ion exchangers, etc.) will also be removed and used correspondingly. Operating personnel is planned to be available for the decommissioning work (project management, planning and operation), because it is most familiar with the power plant. Thus the immediate decommissioning as strategy was selected. The plant site is reserved for power production purposes, e.g., a nuclear power plant can be constructed at the site in the future.

Decommissioning cost estimates should be based on an accurate decommissioning plan. The accuracy of the cost estimate can be rather good if the plant specific radioactive masses and the volumes are properly estimated and the time schedules and manpower calculations are based on proven work efficiencies and proven techniques. Proven techniques are available today. The most difficult task has found to be the dismantling of the biological shield of the reactor pressure vessel. As an average value, cost of decommissioning is about 76,000 FIM/1 m^3 of packaged decommissioning waste (repository included).

REFERENCE

[4-1] Kallonen I., Eurajoki T. and Mayer E., Decommissioning of the Loviisa NPP, Imatran Voima Oy, summary report, 52 p., Vantaa 31 December 1998 (in Finnish).

Annex 5

GERMANY

1. Principle

As in the conventional industrial sector, decommissioning is a necessary follow-up after the useful life of a facility. This can be financed from normal operations (as far as commercial facilities are concerned). It would therefore be short-sighted in both economic and technical terms to consider the decommissioning of nuclear facilities in isolation from their operational phase.

Differences from conventional industrial plants apply only with regard to the outlay to provide radiation protection measures for the population and environment.

In its legal sense, as defined in the Atomic Energy Law [Art. 7 (3) AtG], “decommissioning” denotes only the permanent and final shutdown of a nuclear facility. Safe enclosure and dismantling of the facility (and also disposal of the materials accruing in the course of dismantling) are interpreted as separate actions.

In technical usage, on the other hand, "decommissioning" is generally understood to refer to all the measures carried out after final, permanent shutdown, including safe enclosure and disposal. This more extensive definition also applies for the purposes of this report.

2. Responsibilities

The Federal Ministry of the Environment, Nature Protection and Nuclear Safety (BMU) is responsible for nuclear safety and radiological protection and issues acts and ordinances on behalf of the Federal Government in the licensing procedure. The BMU can give directives to the States to ensure a legally consistent regulatory framework.

The BMU receives advice on all issues concerning nuclear safety and radiological protection from the Reactor Safety Commission (RSK) and from the Commission for Radiological Protection (SSK).

The States act on behalf of the Federal Government as the licensing authorities for construction, commissioning and decommissioning of all nuclear installations. The licensing authorities consult expert organisations for assessment of the Safety Analysis Reports and independent evaluations of all safety issues arising during construction, operation and decommissioning.

3. Policy

Licensing for decommissioning can be achieved within the framework of the existing regulations though only few of them refer specifically to decommissioning. This has been demonstrated by the licensing and implementation of a number of successfully completed decommissioning projects.

The same safety goals used in the operational phase will continue to be used during decommissioning.

The Federal Government is responsible for the development of final waste repositories. There are two repositories for deep geological disposal in different stages of preparation, the licensing of the former Konrad iron-ore mine is already under way, while the salt dome at

Gorleben is being explored. The repository capacities will be sufficient for the existing waste volumes and those projected over the next decades.

4. Decommissioning Policy of the German Power Supply Companies

The German power supply companies assume that their nuclear power stations will be decommissioned and disposed of at the end of their technically and economically service lives. The power supply companies undertook a draw up study assessing the suitability of their nuclear power stations for decommissioning in the mid-1970s. In this study, the decommissioning process is analysed on the basis of two reference nuclear power plants (Biblis A for pressurized water reactors, and Brunsbüttel for boiling water reactors).

This reference study, which is recognised by authorities and specialists alike, is updated on a regular basis, in order to incorporate changes in the licensing situation and experience acquired during the decommissioning of nuclear installations within and outside of Germany. In addition to specifying the technical procedures, the power supply companies have also calculated the decommissioning costs for each individual nuclear power station with the aid of a specially developed software, and these cost assessments are updated annually.

The reference study carried out by the German power supply companies is based on two decommissioning variants, each of which ends in the removal of the nuclear installations from the site of the power station. Each of the variants is preceded by a so-called post-operational phase, which represents the transition from final shutdown to the actual decommissioning process. In this phase, the fuel elements are removed and the operational media and waste are disposed of in accordance with the operating licence for the nuclear power station. The actual decommissioning work cannot be commenced until the licence has been granted.

When the licence has been granted, the post-operational phase is followed by the actual decommissioning phase. Two variants with different time schedules are applied here:

- Decommissioning variant 1 provides for total removal after safe enclosure;
- Decommissioning variant 2 is based on immediate total removal, i.e., the dismantling and removal of all systems and installations belonging to the controlled area is commenced directly after completion of the post-operational phase.

5. Cost and Financing

The funds required for covering the decommissioning costs, are collected in good time, in the form of appropriate provisions. These provisions are accumulated in annual instalments over a 19-year operational period. The expected level of costs is defined considering the basic decommissioning studies described above.

The following areas of work are covered:

- The dismantling and disposal of all components and installations that are located within the controlled area;
- The dismantling and disposal of all parts of buildings that belong to the controlled area;
- All engineering and licensing activities required in connection to the above-stated measures.

The power supply companies have established a basic framework of costs for decommissioning of the two reference nuclear power stations. A comparison of costs for the respective decommissioning variants reveals no difference between the power supply companies' variants 1 and 2 in the case of a pressurised water reactor and only a minimal difference in the case of a boiling water reactor. These costs include the costs of decommissioning, licensing procedures, disassembly, waste conditioning and final disposal charges. They do not include the costs for the disposal of fuel elements, the operating media and operational waste, which are covered by the plant operating costs, as these activities are carried out under the operating licence.

According to information provided by the power supply companies, all costs, this means both the costs for the disposal of fuel elements, for operating media and waste and the actual decommissioning costs, are taken into consideration in the price charged for the kilowatt hours generated by nuclear energy.

6. Summary of regulations, Guidelines and Standards

In Germany, the legal basis for the use of nuclear energy, radiological protection, and related activities is the Atomic Energy Act (AEA) Ꞵ-1β Paragraph 7.3 of the AEA is the central statement relating to the post operational phase of stationary installations for the production, treatment, processing or fission of nuclear fuel or for the reprocessing of irradiated nuclear fuel, and reads as follows:

> *"The decommissioning of an installation as defined in par. (1) as well as the safe enclosure of a finally decommissioned installation or the dismantling of the installation or parts thereof shall require a licence. Par. (2) shall apply accordingly. A licence under the first sentence shall not be required to the extent that the measures planned have already been subject to a licence under par. (1) or of an order under Sec. 9 par. (3)."*

Active steps, such as "safe enclosure" which corresponds to "mothballing" or "entombment", and complete or partial dismantling are distinguished from the general term "decommissioning". This is not explicitly defined, but has to be interpreted as the intention of the operator to finally stop operation. As a first step towards decommissioning, the final shutdown is covered by the operating permit and does not require a special licence.

Decommissioning operations are also regulated - either directly or, more frequently, indirectly - by a large number of additional statutory and technical requirements and regulations at various levels. Presented below is a brief summary of this legal basis.

Of central importance with regard to the decommissioning of all nuclear installations are the regulations concerning approval. Similar to construction and operating measures, all important steps relating to decommissioning require the approval of the competent state authority. Art. 7, para.3, AtG stipulates that a licence is required for decommissioning a nuclear installation, for bringing a permanently shutdown installation in a safe enclosure or for dismantling a plant or plant components; a distinction is made, therefore, between three separate courses of action.

The authority may issue separate licences for individual decommissioning measures or an overall licence for all measures.

Art. 9a, para. 1, AtG pertains to the disposal of waste. This article accords priority to the non-detrimental recycling of materials over disposal as radioactive waste. In practice, this specified priority pertains to the large volumes of metals and building rubble, which are created during decommissioning measures. Art.2, para.2, AtG regulates the conventional disposal of material containing limited amounts of remaining radioactivity. Such waste can be disposed of in the same manner as conventional waste.

Various regulations govern important aspects of decommissioning. Art. 28 of the Ordinance on Radiological Protection (StrlSchV) [5-2] requires the minimisation of all levels of exposure to radiation, including levels below the existing limits (with due regard to the circumstances), while articles 45 and 49 regulate the permissible levels of exposure to radiation in the vicinity of a plant and for the plant personnel. Art. 4, para.5 of the Procedural Regulations for the Atomic Sector (AtVfV) regulates the involvement of the public in applications for decommissioning licences. Art. 12 of the Ordinance on Liability Coverage in the Atomic Sector (AtDeckV) stipulates the amounts of liability coverage for damage caused by nuclear installations.

Under the ordinance level, there are several directives that were initially drawn up for the operational phase, but that are also relevant to decommissioning measures. These include the directive on radiological protection of personnel, the directive on waste management, the recommendations of the Commission for Radiological Protection (SSK), the provisional acceptance conditions for the Konrad final repository and the General Administrative Regulations on Art. 45, StrlSchV. Furthermore, the guidelines issued by the Commission for Reactor Safety (RSK) for pressurised water reactors, and the safety criteria for nuclear power stations as issued by the interstate committee for nuclear energy, require that the design of nuclear power stations should enable decommissioning in compliance with the provisions of the radiological protection regulations, and that a plan should be drawn up for the disposal of the plant after final shutdown.

The atomic energy law and other relevant statutory provisions contain no specific regulations regarding the decommissioning of a nuclear installation. The law indicates that the regulations relating to erection and operation are to be applied analogously. Decommissioning projects or individual decommissioning measures have been approved and carried out on this basis to date, although the analogous application of certain statutory provisions does not provide the authorities responsible for issuing licences with considerable powers of discretion. This largely explains the differences that apply with regard to the procedures adopted by the individual federal states of Germany.

Decommissioning projects have to comply with the Radiological Protection Ordinance. The licensing procedure is governed by the nuclear licensing procedure ordinance.

A basic element of a decommissioning policy is to consider the future requirement to dismantle the plants at both the design and the operational stages.

The Reactor Safety Commission's Guidelines for Pressurised Water Reactors (3rd edition, 14 October 1981) cover the design stage and read as follows:

> *"Decommissioning and Disposal*
>
> *(1) Design and arrangement of buildings, components and systems, and in particular of those components which are activated and contaminated during specified normal operation, shall make allowance for suitable measures for the ultimate decommissioning of the plant, its security and/or its disposal (e.g. separate construction of the inner and outer biological shield).*
>
> *(2) The components to be regarded shall be designed and arranged in such a way as to enable, in case of their disposal, access, decontamination, disassembly and transfer inside the plant with a radiation exposure that is kept as low as possible.*

(3) *The essential provisions and measures for the decommissioning and disposal of the plant as contained in the concept shall be described."*

During plant operation, consideration of decommissioning shall be made as stated in the Safety Criteria promulgated on 21 October 1977, which reads as follows:

"Decommissioning of Nuclear Power Plants

Nuclear power plants shall be in such a condition that they can be decommissioned in compliance with the Radiation Protection Regulations. A concept for the removal of the plant after its final shutdown in compliance with Radiation Protection Regulations shall be provided."

7. Liability Insurance during the Operational and Decommissioning Phases

Removal of the fuel elements in the case of nuclear power stations or removal of highly radioactive waste in case of installations belonging to the fuel cycle represents a considerable reduction in the remaining level of radioactivity in the installation concerned. The following stages of decommissioning are thus carried out on the basis of a markedly reduced risk level.

The atomic energy law (Art. 13) stipulates that the total coverage for statutory liabilities in case of damages to be provided by the applicant must be specified in the course of the licensing procedure. The ordinance on Liability Coverage in the Atomic Sector determines the required levels of coverage, in the case of reactors on the basis of the maximum power output, and, in the case of other nuclear installations, on the basis of the types and quantities of nuclear fuels handled in the installations. When the fuel elements are removed from the installation in the course of decommissioning, this generally results in a marked reduction in the level of coverage required, and in a corresponding reduction in insurance premiums to be paid by the operator or by the owner of the installation.

8. Recent Regulator Initiatives in Decommissioning

Recently, the Commission on Radiological Protection issued a recommendation on the recycling and reuse of steel scrap arising during operation or decommissioning of NPPs Ƀ-4β. It can be expected that these principles will harmonise standards for the release of radioactive materials in Germany. They are important planning criteria for future decommissioning projects.

There are plans to amend the AEA. The major items regarding decommissioning will be:

- Requiring complete dismantling of all radioactive components in due time after final shutdown; and
- Requiring sufficient financial means to dismantle the plant even in case of an unplanned early final shutdown.

9. Guidance on Decommissioning

The BMU has worked out a guide for the decommissioning of facilities licensed according to § 7 of the Atomic Law [5-3]. The guide entails proposals for adequate procedures to be used during decommissioning, especially covering the following issues:

- The use of guidelines and norms below the legal level;
- Planning and preparation of decommissioning;
- Licensing and control.

Due account should be taken to the decreasing potential risk as the work proceeds.

This guidance will help to harmonise the procedures in the German States.

10. Decommissioning Plan

The construction, operation and ownership of nuclear installations require appropriate licences, and competent state authorities inspect the plants on a regular basis, which is normally carried out by the Technical Control Associations (TÜV).

When a licensed nuclear installation is to be decommissioned, the operator or the owner of the plant must apply for a licence. From a legal point of view, the decommissioning process is understood to cover all measures between permanent shutdown and safe enclosure or dismantling of the plant that are not covered by any other licence, such as the operating licence.

For the application, specific documents and information must be provided to the competent state authority in the federal German State in which the considered installation is situated. These documents specify the intended procedure and the effects on the environment, and include information on radiological protection measures, etc. The procedures are regulated in the Procedural Regulations for the Atomic Sector. It should also be emphasised that a decommissioning plan for the installation must be available at the time a licence to erect a new nuclear installation is applied for.

In contrast to other countries, there is no single authority or body, that is responsible for all matters relating to nuclear energy in Germany. Instead, the governments of the individual federal states specify authorities, that are responsible for matters relating to nuclear installations, including granting, withdrawal and cancelling of licences.

The Federal Minister for the Environment, Nature Protection and Reactor Safety (BMU) is notified of licence applications, and is responsible for monitoring and controlling the licensing procedure. For this purpose, he is advised by the Commission for Reactor Safety (RSK) and the Commission for Radiological Protection (SSK). These commissions include independent experts, and their recommendations are drawn up in specialised sub-committees. On detailed points, the Minister also consults the Gesellschaft für Anlagen- und Reaktorsicherheit (Society for Plant and Reactor Safety, GRS), which was founded by the central German government, the federal state governments and the Technical Control Associations (TÜVs). The Minister is also free to consult additional independent bodies. The Federal Minister for the Environment is authorised to issue instructions to the authorities of the federal states.

The competent authorities of the individual federal states have various responsibilities in connection with licensing procedures for decommissioning, safe enclosure or substantial changes in the plant.

These authorities also monitor the construction, operation and decommissioning of nuclear installations and the handling of nuclear fuels outside of these installations.

The application procedure for a decommissioning licence ends with the applicant being notified of the authority’s decision. When the decommissioning licence is granted, the decommissioning activities can usually be commenced. Similar as for construction and operation of nuclear installations, a public announcement is necessary when a decommissioning licence is granted in order to assure the information of the public.

REFERENCES

ΨB-1β Atomic Law. Atomgesetz in der Fassung der Bekanntmachung vom 15 Juli 1985, zuletzt geändert durch Artikel 1 des Gesetzes vom 6 April 1998.

ΨB-2β Radiation Protection Ordinance. Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung) vom 13 Oktober 1976 in der Fassung der Bekanntmachung vom 30 Juni 1989, zuletzt geändert durch die Vierte Änderungsverordnung vom 18 August 1997.

ΨB-3β Guidance on decommissioning of Facilities according §7 of the Atomic Law. Bundesanzeiger vom 14 Juni 1996.

ΨB-4β Clearance of materials, buildings and sites with negligible radioactivity from practices subject to reporting or authorisation. Empfehlung der Strahlenschutzkommission, Heft 16 1998.

Annex 6

HUNGARY

1. Responsibilities

The Hungarian Government, in its decision No. 2414/1997 authorised the Director General of the Hungarian Atomic Energy Authority (HAEA) to establish a company entitled “Public Agency for Radioactive Waste Management” (PURAM). According to this decision PURAM took over the activities relating to collection, treatment, transport, storage and disposal of radioactive waste of small scale producers from the National Public Health and Medical Officer Service [6-1].

PURAM is a fully state owned, non-profit agency and besides the above mentioned tasks PURAM is responsible for the:

(a) Operation of the interim spent fuel storage facility, and of the existing RAW repository;

(b) Extension of the interim spent fuel storage facility;

(c) Selection of sites for new L/ILW and HLW repositories;

(d) Construction and operation the L/ILW and HLW repositories;

(e) Decommissioning of all nuclear facilities in Hungary;

(f) Performing cost calculations in order to define payments to the Central Nuclear Financial Fund.

2. Central Nuclear Financial Fund

Calculations accomplished by PURAM related to the Central Nuclear Financial Fund cover the following topics:

(a) Activities related to L/ILW disposal;

(b) Activities related to HLW disposal;

(c) Radioactive waste transport;

(d) Activities related to the interim spent fuel storage facility;

(e) Decommissioning of all nuclear facilities in Hungary;

(f) Costs related to the Central Nuclear Financial Fund and to all PURAM activities;

(g) Expenses relating to public relations and communications.

2.1. Costs of L/ILW disposal

Site characterisation survey for a L/ILW disposal is in progress since 1993. Between 1993 and 1996 the whole area of Hungary was screened based on the geological archives, to get the suitable geological areas identified. Based on preliminary on-site surveys, which were only performed in areas that got inhabitant’s approval, the surroundings of ÜVEGHUTA seemed to be the most promising site. A disposal facility could be constructed in granite at a depth of 100 to 300 m. For this repository, costs were considered for siting, construction, operation and closure.

To clarify the technical questions and assess the costs relating to the construction of the L/ILW disposal, Hungarian professional institutions and companies of mining and geology were involved.

2.2. Costs of HLW disposal

Ensuing from Hungary's geological structure, a limited number of sites may be available for HLW repositories. One of them is the Permian claystone deposit, called Boda Claystone (or Aleurolite) Formation. Site characterisation explorations that were accomplished indicate that it is a very compact type of rock with very low permeability.

Preliminary exploration started in 1993 aiming to provide a first characterisation of rock that might be selected to host the HLW repository. The costs relating to the construction of the facility were estimated and the same companies and institutions were involved as for the L/ILW repository.

2.3. Waste transport cost estimates

In order to estimate transport costs, data were taken from the international literature. Due to the differences in processing technologies, spent fuel and other HLW materials are considered separately.

2.4. Cost estimation related to the interim spent fuel storage facility

In 1993 it was decided to construct an interim storage facility for spent fuel at the site of the Paks NPP, based on the former GEC Alsthom design. The basic function of the facility is to store the spent fuel assemblies discharged from the units of the Paks NPP for a period of 50 years. In 1997 the operational license of the first modules of the interim spent fuel storage facility was granted by HAEA. If needed in future, the storage capacity may be increased up to 14,850 positions by adding additional modules.

The costs for the construction and operation of the facility were assessed, and its decommissioning costs are included in the decommissioning costs for the Paks NPP.

Since February 2000, PURAM in stead of the Paks NPP is the licensee for the interim spent fuel storage facility. During the next review of the decommissioning study for the Paks NPP, PURAM will therefore provide two independent studies for a separate decommissioning of both nuclear facilities.

2.5. Cost estimates relating to the decommissioning of the Paks NPP

The costs provided for the evaluations in the current document were extracted from the decommissioning study for the Paks NPP, considering the accepted decommissioning strategy.

2.6. Operational costs for the Central Nuclear Financial Fund and for PURAM

The costs related to the Central Nuclear Financial Fund and to all PURAM activities could be accurately estimated as the tasks are well defined by law. The number of employees is well known, as well as average salaries and other additional costs.

2.7. Expenses for public relations and communications

In order to provide on a regular basis information to the population of communities in the vicinity of nuclear facilities, the licensee in Hungary promotes the establishment of a so called "Public Control and Information Association" and may grant assistance to its activities.

Currently, four such organisations exist, respectively in the vicinity of the Paks NPP, the existing waste disposal site, and the sites that are investigated for possible future L/ILW and HLW disposal.

3. Preliminary Decommissioning Study

The decommissioning study [6-2], and its updated [6-3] version has been prepared for three basic options:

(a) Decommissioning to Stage 3, i.e., decommissioning without safe enclosure, starting the decommissioning activities at the end of the operational phase of the plant and terminating with complete unrestricted release of the site (immediate decommissioning to green field conditions).

(b) Decommissioning to Stage 2, i.e., decommissioning with reactor safe enclosure in the reactor shaft for 70 years, and complete decommissioning to green field conditions after the safe enclosure period. Options with a reactor safe enclosure period of 50 and 100 years have been evaluated to compare.

(c) Decommissioning to Stage 1, i.e., decommissioning with closing under surveillance of the nuclear island for 70 years. After the "closing under surveillance" period the NPP is decommissioned to green field conditions.

Second revision of the Decommissioning Study [6-2] began in January of 2002, and was performed simultaneously with compiling this Interim Technical Document. Preliminary calculations accomplished during this revision indicated that related to the earlier versions – having the inflation not considered – causes of the most significant differences are as follows:

(a) waste disposal costs were taken out from the decommissioning costs, as they shall be financed from the Central Nuclear Financial Fund;
(b) expenditures of the 3 year shutdown period (for one unit) were defined precisely and have been taken into account;
(c) also the VAT payment commitments considered, because it was clarified that PURAM as a final customer can not claim back VAT from the Budget.

4. Final Decommissioning Plan

Considering the fact that the first unit of the Paks NPP reaches the end of its scheduled lifetime period in 2012, the deadline for accomplishing a final decommissioning plan is 2011.

The main tasks relating to the final decommissioning plan include the necessity:

(a) to revise periodically the elaborated decommissioning study considering the most actual operational experiences in the Paks NPP, as well as developments in technical know-how and economic conditions during each four years;

(b) to obtain, or develop a Cost Estimating Computer Program, as only the availability of such a tool may enable that decommissioning costs are calculated more accurately and modifications are introduced quickly and in a documented manner.

REFERENCES

[6-1] F. Frigyesi, P. Ormai, A new company in Hungary. Public Agency for Radioactive Waste Management (PURAM), 1998.

[6-2] DECOM SLOVAKIA Ltd., Study of decommissioning the Paks Nuclear Power Plant, Trnava, Slovakia, 1993.

[6-3] DECOM SLOVAKIA Ltd., Study of decommissioning the Paks Nuclear Power Plant, Trnava, Slovakia, 1997

Annex 7

RUSSIAN FEDERATION

1. Responsibilities

In agreement with article 34 of the federal law "About the application of atomic energy" from 20.10.1995, the concern Rosenergoatom as operational organisation was created in order to develop own activities or with the support of other organisations in the area of siting, design, construction, operation and decommissioning of NPPs.

The organisation of decommissioning activities is based on:

- "Documents and orders of the Ministry of Atomic Energy and of the concern Rosenergoatom";
- The guide "Definition of the main relations between organisations and enterprises when developing activities in the area of termination of operation or decommissioning of NPPs".

Based on this documents:

- The operational organisation Rosenergoatom or any other nuclear power plant is defined as a "customer" for decommissioning activities;
- VNIIAES is defined as the leading scientific organisation.

For the implementation of decommissioning activities at NPPs, specific enterprises have been created:

- For NPPs with RBMK type reactors, a specialised decommissioning division has been set up at the Beloyarsky NPP.
- For NPPs with WWER type reactors, a specialised decommissioning division has been set up at the Novovoronezh NPP.

Other specialised organisations are:

- An enterprise involved in the design of NPP decommissioning projects;
- A parent organisation involved in design-technological problems of decommissioning;
- A parent organisation involved in the development of methods and means for the decommissioning of NPPs;
- A leading scientific organisation under the transportation, storage and disposal of radioactive wastes.

2. Special Fund for Financing NPP Decommissioning Activities

According to page 2 of the decree issued by the Government of the Russian Federation on August 5, 1992, about the "Adoption of the regulation relating to the definition of expenses during manufacturing and production operations, and the order to create financial results accepted for taxation of profit", the Ministry of Atomic Energy of the Russian Federation developed and adopted the document "Peculiarity relating to the definition of expenses included in the production costs of a NPP".

In the document, it is ascertained that the production costs of a NPP should include an "Allocation to be reserved in order to cover the expenses relating to the decommissioning of the NPP (of the units separately), rated at 1.3 % of the actual production costs, to be provided for the strictly limited specific use, and to be considered as a proper mandate for the operating organisations."

Based on these documents, a "Reserve to cover the decommissioning costs of the NPPs of the concern Rosenergoatom" was created.

In order to define the decommissioning costs, "A technical and economic calculation of the decommissioning costs for the main units of the NPP" was carried out in 1998. The results of these calculations were considered to be the basis for defining the standard funding to be provided in the "Reserve to cover the decommissioning costs of the NPPs of the concern Rosenergoatom".

Calculations for increasing the standard funding to be provided in the "Reserve to cover the decommissioning costs of the NPPs of the concern Rosenergoatom", may be carried out and directed based on specific considerations of the Government.

3. The Concept of Radioactive Waste Management

The basic concept of radioactive waste management considers that in view of the potential long term risks involved, radioactive wastes should be processed, stored, transported and disposed of in such a way that they should not impose undue burdens on the population or the environment. It is evaluated to store radioactive waste materials in dedicated engineered structures, or in a final disposal area in a geological formation. Storage will be organised such that the radioactive waste materials may be retrieved for repackaging or for removal to another disposal area. Retrieval of radioactive waste materials from final disposal in geological formations is not envisaged. Long term storage of conditioned radioactive waste materials may therefore be organised in storage facilities on the site of a NPP, while disposal in a geological burial area may be the final form of disposition for the radioactive waste materials.

Currently, the only region that is perceived to be acceptable by the public as a possible disposal site for radioactive wastes is the archipelago of the New Earth. The area comprises facilities that were in the past used for nuclear test programmes. Today, access to these facilities is limited or inhibited, but they could be reused to organise the required infrastructure for the disposal of radioactive waste materials.

In order to evaluate the disposal costs for the radioactive waste materials from the NPPs of the concern Rosenergoatom, a "Feasibility study for a possible disposal of radioactive wastes from Russian NPPs on the archipelago of the New Earth" was executed in 1997 [7-1].

The following principles were accepted as initial data for the study [7-1]:

- Processing of low level wastes includes dehydration of resins and pulps, concentration of solutions by evaporation up to a salt content of approximately 300 g/l, and subsequent solidification of the concentrates by cementation;
- Solidified wastes, unconditioned solid low level and intermediate level wastes, incinerated and subsequently solidified low level wastes and compacted low level wastes are transported for burial on a disposal site;
- The costs for the disposal of the radioactive wastes are evaluated considering that the disposal will be in trenches constructed in long frozen layers (except for high level waste that will be disposed of in trenches of a superficial layer).

Based on the collected data, an evaluation of the capital costs and the operational costs for the disposal of radioactive wastes was carried out, as well as a feasibility study for reducing these disposal costs. The resulting figures were used in order to evaluate the decommissioning costs for the NPPs [7-2].

4. Decommissioning Plan

Planning and management of the activities in order to prepare the decommissioning of the various units of the NPPs are effectuated based on the decommissioning programmes that were developed and authorised for the units 3 and 4 of the Novovoronezh NPP, and the units 1 and 2 of the Kola NPP comprising WWER-440 reactors. The programmes include a main list of organisational and technical measures and activities that need to be carried out for the decommissioning of the NPP [7-3], [7-4]:

- Preparation of the units for decommissioning, starting five years before expiration of the 30 years' period of service life;
- Final shutdown of the unit and start of the practical activities for preparing the unit for decommissioning;
- Decommissioning of the unit of the NPP.

The decommissioning programme is included in the list of documents presented to Gosatomnadzor in order to obtain the decommissioning license.

The main tasks included in the decommissioning programme are [7-3], [7-4]:

- Development of a plan to remove the spent fuel from the cooling pools and bringing the units in a nuclear safe condition;
- Development of the first decommissioning stage, "Preparation of the Novovoronezh NPP unit 1 for safe enclosure under surveillance", including the decommissioning cost estimate;
- Implementation of an integral inspection of the units;
- Development of the list of documentation for obtaining the license from Gosatomnadzor for operating the units in the shutdown phase;
- Obtaining the license from Gosatomnadzor for the decommissioning of the shutdown units of the NPP.

REFERENCES

[7-1] Feasibility study for a possible disposal of radioactive wastes from Russian NPPs on the archipelago of the New Earth, "Small power" Ltd., Moscow, 1997.

[7-2] Feasibility study for the decommissioning of the units of the NPP, Moscow, Russia, 1998.

[7-3] Concept for the decommissioning of a NPP unit after expiration of its lifetime, 1991.

[7-4] Guide with "Main rules for the decommissioning of a NPP unit, RD EO 0013-93, 1993.

Annex 8

SLOVAKIA

1. Introduction

There are six operating WWER-440 reactors at two nuclear localities in Slovakia:

- Jaslovské Bohunice: two 230-type (NPP V-1), commissioned in 1978 and 1980.
- Jaslovské Bohunice: two 213-type (NPP V-2), commissioned in 1984 and 1985.
- Mochovce: two 213-type, commissioned in October 1998 and February 2000.
- Mochovce: two 213 type under construction (no state warranty for completion).

The Slovak Government decided that the V-1 nuclear power plant at Jaslovské Bohunice should be shutdown in 2006 (1st reactor) and 2008 (2nd reactor). Currently, the NPP A-1 (150 MW(e), HWGCR type) at Jaslovské Bohunice is being decommissioned. It was shutdown in 1979 after suffering from various technical problems and two accidents in the 1970s. The Slovak NPPs together with other strategic energy resources belong to the Slovak Electric, plc., a joint stock company with 100 % ownership of the state.

2. Responsibilities

The Governmental Decision No. 190/1994 determined the basic strategy for radioactive waste management in Slovakia. Based on this Decision, a new company "Nuclear Installation Decommissioning, Radwaste Processing and Spent Fuel Management" was established in 1996, as a subsidiary of Slovak Electric, plc. The responsibility of this company is conditioning and disposal of radioactive wastes from operations and from decommissioning, and decommissioning of nuclear facilities.

3. Funding

In 1995 the State Fund for NPP decommissioning, including spent fuel and radioactive waste treatment and disposal, was established. The owners of NPPs are obliged to contribute to this fund 10 % of the market price of the energy sold to the grid. The state is another source of income for the fund. The existence of this fund created the possibility to commence the decommissioning activities at the NPP A-1 and to prepare the documentation for the decommissioning of WWER reactors.

4. Spent Fuel Management

In 1987, a wet fuel storage facility was commissioned with storage capacity for about 10 years of spent fuel production (5,040 fuel assemblies). In the early 1990s, the transfer of spent fuel to Russia was stopped. It was decided, therefore, to increase the wet storage capacity in Jaslovské Bohunice in order to accept the spent fuel production during the full operation lifetime of the NPPs V-1 and V-2 (14,112 fuel assemblies).

The increased storage capacity will be achieved by designing and constructing new storage baskets. The seismic resistance of the storage will be increased to the level required by the international recommendations. After reconstruction the storage facility will be re-licensed and the storage period will be extended to 50 years. It is expected that after this period the deep geological repository for spent fuel will be available.

Relating to the spent fuel from the reactors in the Mochovce NPP, it is supposed to construct a dry storage facility using CASTOR type storage casks. No final decision has been taken yet.

5. Waste Management

5.1. Waste treatment and conditioning

A new and recently licensed treatment and conditioning centre (the Bohunice Conditioning Centre at the Jaslovské Bohunice site) for liquid and solid radioactive wastes is under active testing. It comprises the following three basic conditioning technologies:

∉# Cementation of liquid radioactive wastes;

∉# Incineration of solid and liquid burnable wastes;

∉# High-pressure compaction of solid waste.

The centre produces waste packages, i.e., fibre reinforced concrete containers that are accepted at the Mochovce repository. A container with conditioned waste material (200 l-drums, end products from high pressure compaction at this time) is filled with cement mortar.

Other conditioning technologies at the Jaslovske Bohunice site are:

∉# Bituminisation of liquid wastes;

∉# Fragmentation of metal wastes with contamination up to $3x10^6$ kBq/m^2;

∉# Vitrification of high level and alpha-bearing liquid wastes, commissioned in 1996.

5.2. Waste storage

Various liquid wastes (concentrates, spent ion exchange resins), and solid or solidified wastes (mostly in 200 litre drums) from operations are stored in each NPP waiting for their final conditioning in the Bohunice Conditioning Centre.

Some empty compartments inside the NPP A-1 were reconstructed and licensed as storage facilities for conditioned waste. The construction of a centralised storage facility for various conditioned wastes, located on the Jaslovske Bohunice site, is currently under study.

5.3. Waste disposal at a near surface repository

The near surface disposal site for low level radioactive waste at Mochovce, located at 1.5 km from the Mochovce NPP, was established in 1992-1993. After regulator and operator interventions (with participation of the IAEA, that was requested to effectuate a peer review on the facility’s preparedness for operation), and after essential adaptations, the facility was finished in 1997-1999. The decision and the approval to start test operations in the facility was issued by the Slovak Nuclear Regulatory Authority in October 1999.

The disposal facility consists of 40 concrete vaults organised in two double rows. A compacted clay tube around the individual double rows was designed and constructed as the fundamental engineering barrier for the facility. The waste packages are metallic fibre reinforced concrete containers (3.1 m^3 inner volume) that may contain various conditioned wastes and be filled with active or non-active cement mortar. The existing capacity of the disposal facility (7,200 containers) could be sufficient for disposal of the operational wastes of both operating NPPs, as well as for the low level short-lived wastes from the decommissioning of the NPP A-1.

5.4. Deep Geological Repository

The complex project for the development of a deep geological repository started in 1996 as a logic continuation of previous activities in the former Czechoslovak Federation. At the present time, the project activities continue within Slovak Electric, plc., and are co-ordinated by DECOM Slovakia. The project is divided into three parts:

- The facility siting process;
- A safety and performance assessment;
- Co-ordination activities including involvement of the public, evaluation of waste and spent fuel management legislation and state infrastructure, preparation of annual progress reports, feasibility and design studies developed during the project.

According to the project planning, it is intended to finish the siting process after 2010, and to accept the first spent fuel containers for disposal after 2030.

6. Legislative Aspects

6.1. The Decommissioning Process

The most important legal provisions are the Atomic Energy Act, the Act on Protection of Population and a Decree on Nuclear Safety in Radioactive Waste Management. The legislation defines the responsibilities, the roles and the authorities for all the organisations involved in the design, manufacturing, operation, waste management and decommissioning of nuclear installations. The licensee is responsible for implementation of the decommissioning operations.

The policy relating to nuclear facilities decommissioning, the role of the operator and the role of the Nuclear Regulatory Authority of the Slovak Republic are defined in the Act on Peaceful Utilisation of Nuclear Energy (Atomic Energy Act, Act No. 130/1998). In the relevant part of this Act, decommissioning is defined as the safe removal of a nuclear facility from service and the reduction of the residual radioactivity to a level permitting release of property for reuse as a nuclear facility, or site release and termination of the licence.

6.2. Clearance Levels

The Ministry of Health is the authority for establishing the criteria for site release and clearance or authorised release of materials (Act No. 272/1994 and amendments) in accordance with the IAEA/NEA guidance (Safety series No. 89) on exemption/clearance principles, and based on a limit for the effective dose to the average member of the critical group of 0.01 mSv/a from each exemption/clearance practice and a limit for the collective dose of 1 mSv/a.

Clearance levels of 3 kBq/m^2 (beta, gamma), 0.3 kBq/m^2 (alpha) for surface contamination of released metal materials and 0.1 kBq/kg for the specific activity (above the natural background activity) were established as well as the conditions for measuring these values.

The derived criteria for metal scrap remelting are also defined in this Act. The criteria are based on an activity reduction and dilution by melting, and enables remelting and authorised release for reuse of metals with a specific activity that is 10 times higher than for clearance. The total activity of the material removed for remelting from one site should be less than or equal to 1 GBq/a.

6.3. Social Aspects

The Act of the National Council of the Slovak Republic, No. 157/1994, considering the development of an environmental impact assessment for all new industrial activities, including the proposed decommissioning of a NPP, establishes the responsibilities and the authority of the licensee and all involved parties.

The environmental impact process includes the preparation of an appropriate study by the licensee, hearing of citizens in local and neighbouring NPP municipalities, and authorities as well as other stakeholders. The statement of the Nuclear Regulatory Authority, the Ministry of Health and other regulatory bodies are required in order to define the final point of view.

6.4. Documentation

The extent of the documentation that must be submitted to the Nuclear Regulatory Authority for licensing and terminating the decommissioning activities is defined in a Decree on Documentation of Nuclear Facilities for Decommissioning, No. 246/1999. The basic document is the actualised conceptual plan for decommissioning with alternative technical solutions for the decommissioning operations. The basic structure for these technical alternatives is defined. Other main documents are:

- Limits and safety conditions in decommissioning;
- Quality assurance plan;
- Emergency plan; and
- 9 other documents, relating to plans of individual decommissioning phases, waste management, radiological protection, funding, etc.

In the Act also the content of the required final documentation is defined, including a description of the final state of the site, exposure data, waste data, data to be further archived, results of independent final radiation surveys, criteria for releasing the site and documentation on meeting this criteria.

Annex 9

UKRAINE

1. Introduction

At present the power industry of the Ukraine is to a large extent based on the use of nuclear energy. In 1999 the share of electricity generated by nuclear units was about 42 % of the total electricity generation in the country. After the final shutdown of the Chernobyl NPP in December 2000, there are 13 operating nuclear units in the Ukraine with a total installed capacity of 11,818 MW(e). These units are located at four NPP sites (see the table). All Ukrainian NPPs are operated by the National Atomic Energy Generating Company "Energoatom".

NPP site	Unit Number	Reactor type	Installed capacity, MW(e)	Start of commercial operation	End of design life time
Rovno	1	WWER-440	402	1981	2011
	2	WWER-440	416	1982	2012
	3	WWER-1000	1000	1986	2016
	4*	WWER-1000	1000		
South Ukraine	1	WWER-1000	1000	1982	2012
	2	WWER-1000	1000	1985	2015
	3	WWER-1000	1000	1989	2019
Zaporozhye	1	WWER-1000	1000	1984	2014
	2	WWER-1000	1000	1985	2015
	3	WWER-1000	1000	1986	2016
	4	WWER-1000	1000	1987	2017
	5	WWER-1000	1000	1989	2019
	6	WWER-1000	1000	1995	2025
Khmelnitsky	1	WWER-1000	1000	1987	2017
	2*	WWER-1000	1000		

* - under construction; expected year of commissioning is 2003.

Normally, the design lifetime of a NPP unit with a WWER type reactor should expire after 30 years of operation. As a result, the initially designed closure of these units should occur in the period from 2011 to 2025. Currently, it is planned to extend the operational period up to 40 or 50 years depending on the specific conditions of the unit, but all required measures to be ready for decommissioning are planned and have to be carried out before the end of the 30 years operational period.

2. Legislation

Ukraine has a well-developed national legislation and regulations in the field of peaceful use of nuclear energy. The Ukrainian Law, "On Nuclear Energy Use and Radiation Safety" (1995) establishes the main principles and priorities for a safe use of nuclear energy that regulate the activities in the nuclear field. The impact of this Law fully extends to all decommissioning activities. Other laws relevant to decommissioning are the Ukrainian Laws "On Human

Protection Against Ionising Radiation Impact" (1998), "On Radioactive Waste Management" (1995) and "On Permissive Activity in the Field of Nuclear Energy Use" (2000).

Like all other nuclear operations, the safety of decommissioning activities is regulated by a set of existing regulations:

- "General Regulations for Nuclear Power Plant Safety" (OPBU-2000);
- "Main Sanitary Rules for Work with Radioactive Materials and Other Sources of Ionising Radiation" (OSP-72/87);
- "Norms of Radiation Safety of Ukraine" (NRBU-97/2000);
- "Safety in Transportation of Radioactive Substances" (PBTRV-73);
- "Rules of Radiation Safety during Plant Operation" (PRBAS-89);
- "Sanitary Rules of Design and Operation of NPPs" (SP-AS-88);
- "Sanitary Rules of Radioactive Waste Management" (SPORO-85);
- "Rules and Order of Exemption of Radioactive Waste and By-product Radioactive Materials from Regulatory Control" (1997).

The regulatory document "General Provisions on Safety Assurance of Decommissioning of Nuclear Power Plants and Research Reactors" (1998) contains the main safety requirements for decommissioning and defines the decommissioning stages as well as the content of activities at each stage without a limitation for their duration. The following decommissioning stages are established:

- Final closure;
- Preservation;
- Long-term storage;
- Dismantling.

This document enables an operator to execute independently the planning and implementation of decommissioning activities.

3. Waste Management

The current activities relating to radioactive waste management in the Ukraine are carried out in accordance with the initial design of NPPs, and do not foresee the processing of solid radioactive waste. The initial conditioning of the liquid radioactive wastes from operations and their temporary storage are carried out on the sites of the NPPs. The existing systems for radioactive waste management do not provide the required conditioning of the waste, however. Consequently the stored radioactive wastes have a form that is inconvenient for further processing. Solving these problems relating to processing and storage will be feasible after implementation of a "Complex Programme of Radioactive Waste Management" that was accepted in 1996 and amended in 1999. This Programme foresees the creation of a two-level system of radioactive waste management, consisting of two sub-systems:

- A sub-system with preliminary radioactive waste processing on the sites of the NPPs;
- A sub-system with final radioactive waste processing carried out in a specialised facility, and including further transfer for long-term storage or burial in a centralised storage facility.

The first sub-system will include the installations for radioactive waste processing and conditioning, the temporary waste storage facilities and the equipment for radioactive waste transportation, including special transport means and containers.

The basic element of the second sub-system is the central plant for radioactive waste processing and disposal, where complex processing technologies will be used for all kinds of low and intermediate level wastes from the NPPs as well as for the secondary waste arising from operations. The plant is designed for the processing of radioactive wastes originating from the operation of the nuclear units and their decommissioning. The programme foresees the construction of the central plant in the Chernobyl operational area. The first set of the central plant facilities should be commissioned in 2002.

4. Spent Fuel Management

Current practice of spent fuel management in the Ukraine is based on the technical solutions that were initially included in the design of NPPs with WWER type reactors. After being discharged from the core, the spent fuel is stored in the reactor pools for at least three years. An intermediate storage facility for spent fuel was not available in Ukraine, as the spent fuel elements were shipped back to the Russian Federation for further utilisation.

Today, the strategy relating to spent fuel management includes both options, spent fuel transport to the Russian Federation for utilisation as well as creation of a national system for dry storage of spent fuel, that will provide safe spent fuel storage during at least 50 years. Relating to the last option, the final stage of spent fuel management, i.e., reprocessing or disposal, is not yet uniquely determined.

The first step in creating a storage system is the construction and commissioning of the dry storage facility at the site of the Zaporozhye NPP (ZNPP). The feasibility to construct such a storage facility on sites of other NPPs or to construct a centralised storage facility will be considered after the experimental-industrial operation of the facility on the site of the ZNPP.

5. Responsibilities

According to the Ukrainian Law "On Nuclear Energy Use and Radiation Safety" decommissioning is considered as one of the elements of the life cycle of a nuclear facility and the licensee should be granted to carry out the activities relating to decommissioning. The Law establishes that the decommissioning activity is only permitted under a decommissioning licence that must be issued on the basis of a project safety assessment. The decommissioning licence comes into force only after the facility has been put in nuclear safe conditions, which means absence of nuclear fuel on site or fuel removed to an on-site nuclear fuel storage facility. As soon as the decommissioning licence is in force the previous operating licence is cancelled and cannot be resumed. The decommissioning licence includes the reception of separate permissions to implement each decommissioning stage.

6. Decommissioning Funding

According to the Ukrainian Law "On Nuclear Energy Use and Radiation Safety", the financing of decommissioning of nuclear installation shall be provided by the owner. The owner transfers money into a decommissioning fund and includes the expenses for decommissioning into the electricity price. The mechanism of accumulation of financial resources for decommissioning should be in force during the whole period of commercial operation of the facility. As the responsibility of the owner for the accumulation of money for future NPP decommissioning was determined by national legislation only a few years ago, the principles and the rules for the creation and the functioning of the decommissioning fund are currently elaborated.

7. Decommissioning Plan

The decommissioning programme for the WWER units in the Ukraine is currently in its early stage. Until now, mainly preliminary studies have been developed. As early planning will facilitate execution of the decommissioning activities and reduce costs, the general approach is to elaborate as soon as possible the concept for the decommissioning of the NPPs of the Ukraine. This concept should be the basis for developing the decommissioning programme for each individual unit considering their common design features. The work relating to this decommissioning concept is currently in progress.

ABBREVATIONS

AEA	Atomic Energy Act
ALARA	As Low As Reasonably Achievable
ANPP	Armenian Nuclear Power Plant
BMU	Federal Ministry of the Environment, Nature Protection and Nuclear Safety
BWR	Boiling Water Reactor
CAD	Computer Aided Design
CECP	Cost Estimating Computer Program
D&D	Decontamination and Dismantling
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECCS	Emergency Core Cooling System
EU	European Union
GDP	Gross Domestic Product
HAEA	Hungarian Atomic Energy Authority
HLW	High-Level waste
HWGCR	Heavy-Water-Moderated Gas Cooled Reactor
IAEA	International Atomic Energy Agency
ILW	Intermediate-Level Waste
ISO	International Organisation for Standardisation
JPNAS	Joint Parallel Nuclear Alternative Study
L/ILW	Low and Intermediate Level Waste
LLW	Low-Level Waste
LWS	Liquid Waste Storage
MVDS	Modular Vault Dry Storage
PNNL	Pacific Northwest National Laboratory
PURAM	Public Agency for Radioactive Waste Management
PWR	Pressurized Water Reactor
RAW	Radioactive Waste
RAWRA	Radioactive Waste Repositories Authority
RBMK	Light-Water-Cooled Graphite-Moderated-Reactor
RPV	Reactor Pressure Vessel
RSK	Reactor Safety Commission
SF	Spent Fuel
SI	International System of Measurement
SONS	State Office for Nuclear Safety
SSK	Commission for Radiation Protection
STUK	Radiation and Nuclear Safety Authority of Finland
SWC	Special Water Cleaning
VNIIAES	All-Russian Research Institute for NPP Operation
WWER	Water Cooled Water Moderated Power Reactor

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