Costs of decommissioning nuclear power plants

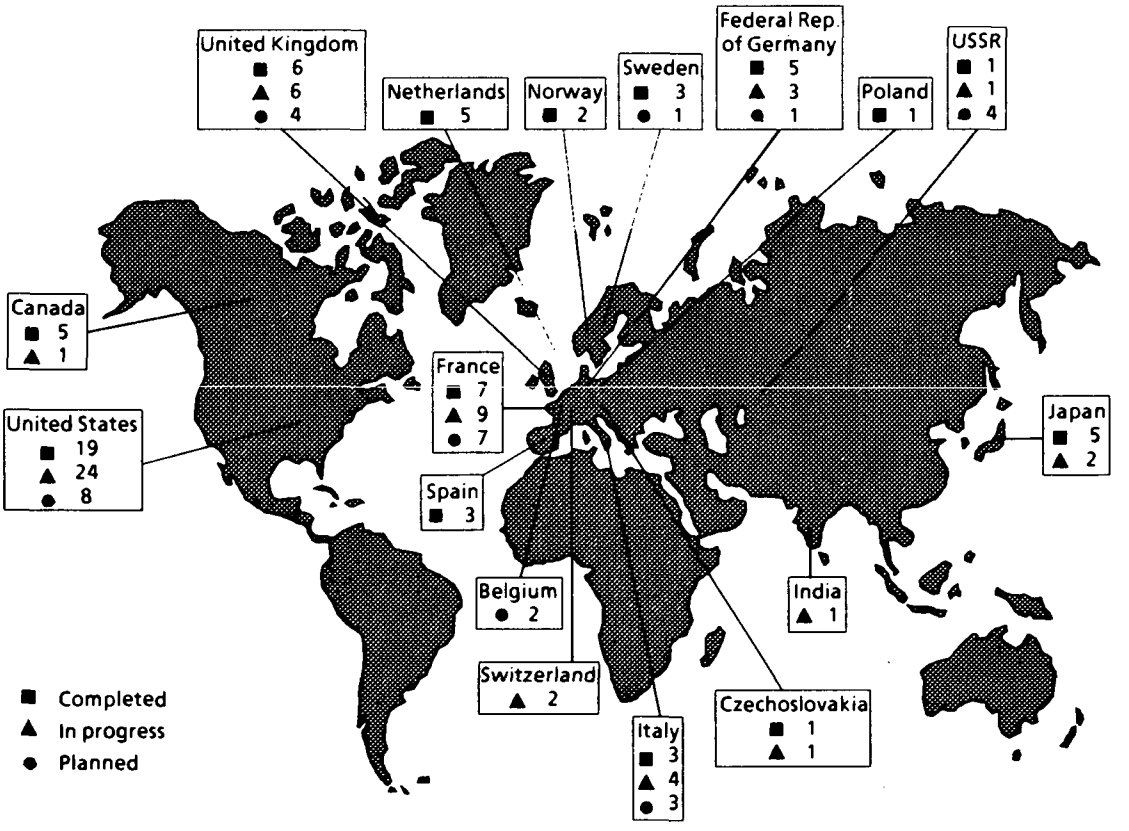
A report on recent international estimates

by Pabitra L. De

Over the past 35 years, considerable experience has been gained in decommissioning many types of nuclear facilities. These include prototype power plants, research reactors, fuel cycle facilities, and laboratories. Worldwide, some 150 nuclear facilities in 17 countries are listed in the IAEA's inventory of decommissioning projects as either completed, in progress, or planned.* *(See map.)*

By the turn of the century, more than 60 nuclear power plants and 250 research reactors around the world

Nuclear decommissioning projects around the world



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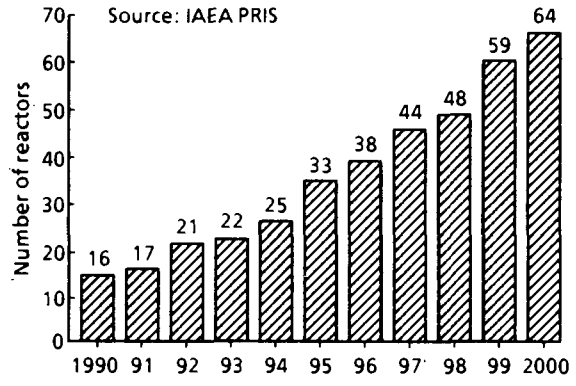
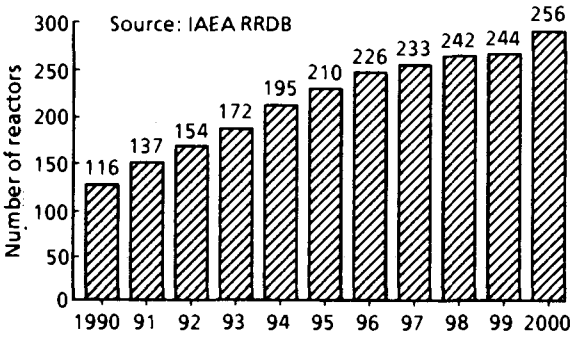
* *Methodology and Technology of Decommissioning Nuclear Facilities*, IAEA Technical Reports Series No. 267, Vienna (1986).

Nuclear power plants likely to be decommissioned



Nuclear research reactors likely to be decommissioned



Decommissioning stages

As defined by the IAEA, the three stages of decommissioning nuclear facilities are:

- Stage 1 (sometimes referred to as storage with surveillance)
- Stage 2 (sometimes referred to as restricted site release)
- Stage 3 (sometimes referred to as unrestricted site use).

The term "stage" implies a set of conditions at the plant and does not necessarily imply a continuing step-by-step procedure. Although Stage 1 and Stage 2 are available decommissioning options, most countries consider them as interim modes leading eventually into Stage 3.

will become likely candidates for decommissioning. *(See accompanying figures.)*

The term "decommissioning", as used in the nuclear industry, means the actions taken at the end of a facility's useful life to retire it from service. These actions can range from merely closing down the facility and a minimal removal of radioactive material coupled with continuing maintenance and surveillance (Stage 1), to removal of all unacceptable radioactive material from the facility soon after shutdown (Stage 3). All decommissioning activities can be done in a manner that provides adequate protection for the health and safety of the decommissioning workers, the general public, and the environment.

The ultimate goal of all decommissioning work is to clean up any radioactive material from the site so that it can be reused without any radiological restrictions. In this connection, the IAEA has defined three stages of decommissioning that have become internationally accepted. *(See box.)*

Several factors influence the choice of decommissioning strategy in a country. The overall programme of nuclear power development is a major factor. However, the degree to which individual national approaches differ among themselves is very large and can be characterized as follows:

- In some countries, a safe storage period (Stage 1) from 5 to 10 years prior to the start of Stage 3 decommissioning is being considered.
- In other countries, the strategy is based on implementing Stage 1, possibly taking further steps towards Stage 2, while deferring implementation of Stage 3 for several decades (up to 100 years).
- In some countries, the decommissioning strategy is to go to Stage 3 as soon as practical with the aim of reusing the site for other purposes.

Decommissioning costs

Although no large-scale commercial power plant has yet been decommissioned, the cost estimates, based on experience gained with smaller plants and with maintenance-related activities in large nuclear plants, are fairly representative. Several factors directly affect decommissioning costs: the type of nuclear facility, the decommissioning option or stage chosen, project duration, waste disposal practices, the rate of inflation, discount rates, etc. Because of these variables, decommissioning costs will differ from country to country, as well as from plant to plant.

In many countries, the cost of reprocessing spent fuel and the disposal of resulting high-level waste, or the disposal cost of spent fuel, is considered as a part of fuel costs. Similarly, disposal cost of operational waste is considered as a part of plant operation and maintenance (O & M) costs. For such countries, these costs are, therefore, not included in the decommissioning cost projections.

The most reliable estimate of decommissioning costs can only come from an engineering study of a particular plant in a specific country. Generic cost estimates, however, should provide a good basis for initial planning. It should be noted that since decommissioning activities require a minimum organizational and technical infrastructure, the absolute costs of decommissioning smaller plants may not, therefore, be significantly different from those for larger plants. The cost per kilowatt-electricity of small plants is high and should not be extrapolated linearly to large plants; instead economies of scale should be taken into account.

A report by an Expert Group convened by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) on decommissioning concluded that decommissioning was technologically feasible, the waste volumes were manageable, and that decommissioning costs had a very small impact on the electricity generation costs.*

On an annual basis, the funding required (costs) for decommissioning of a large commercial reactor would be 2%–5% of electricity generation costs. The conclusion was based on decommissioning cost estimates from Canada, the Federal Republic of Germany, Finland, Sweden, and the United States.

In spite of the uncertainties in estimating the decommissioning costs, applicable real discount rates, or reactor operating lifetime, the above conclusions are unlikely to be altered.

A recent study by the International Union of Producers and Distributors of Electrical Energy (UNIPEDE) provided decommissioning costs from the perspective of "construction costs", rather than "electricity generation costs" as in the NEA study.** It concluded that decommissioning costs range from 10%–20% of the plant construction or capital cost. It should be noted that plant construction cost is only one component of the electricity generation costs, which also include O&M and fuel costs. Conclusions from the UNIPEDE study were thus found consistent with the NEA findings.

The cost of nuclear (and conventional) electricity is an important parameter for decisions on future electricity supply. In view of this, surveys were conducted by the IAEA primarily for developing countries and by the NEA/OECD and International Energy Agency (IEA) for the OECD countries.*** The cost estimates are spread over a wide range, from US $130 million to $477 million.

The decommissioning costs from developing countries, which resulted from the IAEA survey, show that Czechoslovakia, India, Indonesia, the Republic of Korea, Poland, and Yugoslavia assumed undiscounted decommissioning costs of US $60 million to $163 million. Details on the decommissioning option or stage were not provided for this study which may explain the cost divergence. Brazil, China, Hungary, and Turkey did not make their own assumptions on decommissioning. For these countries, the study assumed that 10% of the construction or capital cost will provide adequate coverage for decommissioning, the total cost ranging from US $124 million to $235 million. *(See accompanying tables.)*

Decommissioning costs in OECD countries

	Specific plant type and size	Cost, January 1988 (millions of US $)
Belgium	PWR 1390 MWe	207
Canada	HWR 881 MWe	196
	HWR 400 MWe	164
Finland	PWR 1000 MWe	189
France	PWR 1390 MWe	208
Germany, Fed. Rep. of	PWR 1256 MWe	280
Italy	PWR 945 MWe	477
Japan	LWR 1100 MWe	221
Netherlands	PWR 1300 MWe	320
Spain	PWR 950 MWe	268
United Kingdom	PWR 1175 MWe	380
United States	PWR 1144 MWe	130

Note: Results are from a joint 1988 NEA/IEA survey. Costs are estimates based on questionnaire responses.

Decommissioning costs in developing countries

	Plant capacity	Per cent of investment	Decommissioning cost	
			US $/kWe	Millions of US $
Brazil*	1245 MWe	10	170	212
China*	900 MWe	10	138	124
Czechoslovakia	916 MWe	10	132	121
Hungary*	950 MWe	10	190	181
India	450 MWe	25	363	163
Indonesia	1000 MWe	6	95	95
Korea, Rep. of	940 MWe	4	64	60
Poland	940 MWe	8	117	110
Turkey*	1066 MWe	10	220	235
Yugoslavia	1000 MWe	4	95	95

* 10% of initial investment cost assumed by IAEA staff.

Note: Costs are estimates based on responses to an IAEA survey in 1988–89.

* *Decommissioning of Nuclear Facilities: Feasibility, Needs, and Costs*, a report by an Expert Group, NEA/OECD, Paris (1986).

** "Operators' Views of Key Issues Confronting Nuclear Power and Decommissioning", by J. Essmann, UNIPEDE, a paper presented at the 1989 CEC International Conference on Decommissioning of Nuclear Installations, Brussels (October 1989).

*** *Projected Cost of Generating Electricity*, OECD, Paris (1989); and *Projected Cost of Nuclear and Conventional Baseload Electricity Generation in Some IAEA Member States*, IAEA-TECDOC-569, Vienna (1990).

It is apparent that the published decommissioning cost estimates vary considerably from site to site and country to country. There are considerable public misgivings about "true" decommissioning costs (and perhaps also about the technical community's ability to perform future decommissioning).

Under the auspices of the NEA/OECD, an Expert Group was, therefore, recently set up to assess if the variability of decommissioning cost estimates can be explained, with a view to enhancing the comfort and confidence of the informed public and policy makers regarding nuclear power in general and decommissioning in particular. Eleven countries and two international organizations are participating in this Expert Group. Results of this study are expected around the middle of next year.

Financing of decommissioning costs

Decommissioning is considered as part of the plant's life cycle (back-end). As such, costs of decommissioning should be borne by the electricity consumers who benefit from the plant. This notion has been generally accepted by many countries. However, financing methods for decommissioning vary from country to country. A number of options exist and are being practiced to finance nuclear plant decommissioning. The most common options are: prepayment, external sinking fund, internal reserve, surety fund, letter of credit, or insurance.

At one extreme approach, a lump sum can be set aside at the beginning of plant operation. At the other extreme, a lump sum can be set aside at the end of the plant's life. An intermediate approach is the collection of funds gradually during plant operation, with the funds set aside in an internal or external special reserve account.

Conclusion

As most decommissioning cost estimates are performed with different and specific objectives in mind, and hence different scopes of work, it could be misleading to compare these estimates, unless they are sufficiently qualified or explained. Generic cost estimates can provide a good basis for initial planning. However, the most reliable estimate can only come from a site-specific study.

International efforts to harmonize the various estimates are essential, for which it is perhaps desirable to explore and pursue an internationally accepted "common" methodology for decommissioning cost estimation.

The recent NEA initiatives to interpret the apparent divergence of cost estimates is a move in the right direction. The IAEA introduced the concept of various cost elements or components and a suggested methodology in its 1986 technical report *Methodology and Technology of Decommissioning Nuclear Facilities*. It has also undertaken, in its 1991–92 programme, some specific studies on a common methodology for decommissioning cost estimation.

It is hoped that these international efforts will bring about a better understanding of the proper costs of decommissioning nuclear power plants in the future.

Dismantling of Shippingport nuclear plant in the USA. (Credit: US DOE)