Economics of spent-fuel storage

A description of the methodology developed by the IAEA for analysing costs

by José L. Rojas de Diego

There are three different strategies in the back-end of the nuclear fuel cycle: the once-through cycle including final disposal of spent fuel; the open cycle, in which this fuel is stored on an interim basis with the possibility of either future retrieval or final storage; and the closed cycle, in which spent fuel is reprocessed and recovered uranium and plutonium are recycled.

Spent-fuel storage conceptually includes both interim and final storage methods, although final disposal has not yet been demonstrated. Over the next 30–50 years, final storage facilities will have to be constructed for those countries having selected this strategy. Therefore, interim storage of spent fuel, allowing for future retrieval, is a very important strategy to take into account in many policy-making processes.

The main purpose of this article is to discuss briefly the economics of spent-fuel storage options following a methodology developed by the IAEA for calculating the different costs of storage and analysing them in an adequate way.* In particular, it deals with the impact of storage quantity, storage period, storage methods, financing, and the process from planning and construction through decommissioning of a spent-fuel storage facility.

Costing considerations

The total costs of storage must be based on a detailed technical assessment of the kind of fuel to be stored and the storage option selected, taking into account all possible technical characteristics.

For a precise cost calculation, it is necessary to realize first of all that some basic parameters affect all possible options, with strong influence on the design of the storage facility. These include the quantity of fuel to be stored (capacity); planned operating schedule; storage period; retrieval schedule; and spent-fuel characteristics.

The different costs of a storage facility can be classified in cost categories and cost components. The categories include initial development, investment, operation, on-going development, transportation, and decommissioning.

Within each category there are different components which should clearly be distinguished in order to obtain a good cost calculation.

For example, in the investment cost, the most significant components include land acquisition, site preparation, design and engineering, building and construction, process equipment, instrumentation equipment, and commissioning.

In the operating costs, components that must be considered include labour, materials and goods, services, energy, maintenance, waste conditioning and disposal, rates and insurances, and quality assurance.

In the initial development costs, one significant component should be the licensing and regulation costs, which influence the operating costs if subsequent annual payments are required by regulatory authorities.

Cost analysis

Once the different cost components and categories have been defined and calculated to make an appropriate economic choice, it is necessary to aggregate them conveniently by an economic analysis. The time series of all future costs may be equivalent to a representative cost known as the "net present value" (NPV), in such a form that if a number of options exist, the most economic one is the one having the lowest NPV.

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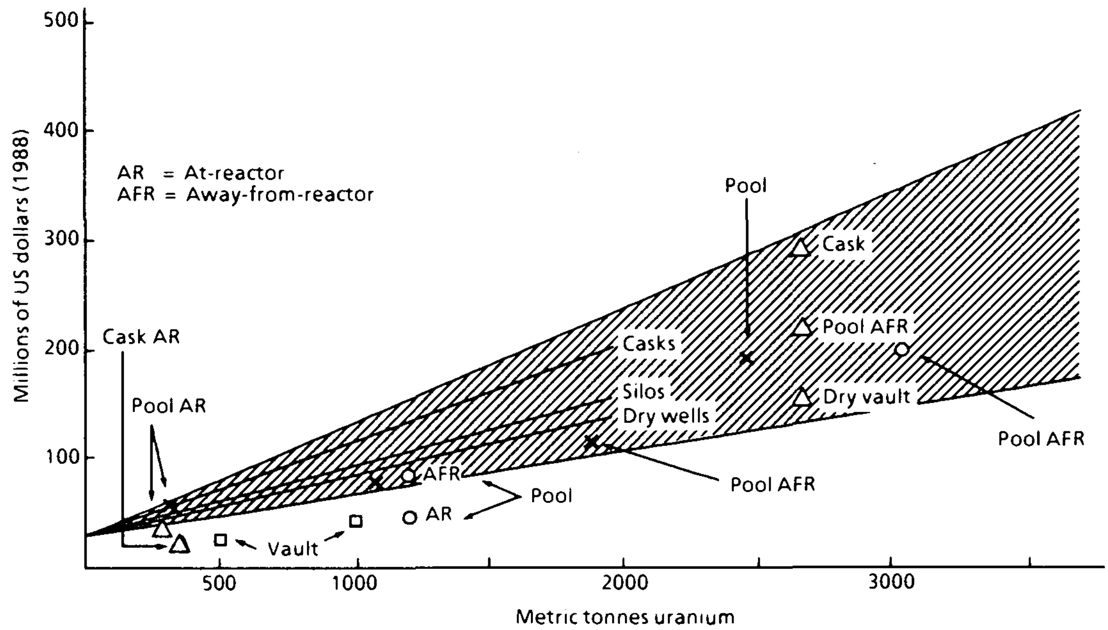
* The IAEA is preparing for publication a technical report, *Methodology on Economics of Spent Fuel Storage*, which contains more comprehensive information than the brief analysis presented in this article.

Spent-fuel storage investment costs versus capacity



The NPV is obtained by discounting all costs to one common date, and applying the adequate discount rate to the series of annual costs (annual cash-flows).

Correlation of the different cost categories

In analysing the economics of spent-fuel storage, it is very difficult to draw conclusions or correlations from the very different cases studied (more than 300 references have been considered by the IAEA), and uncertainties exist. In the analysis briefly reported here, the most important cost categories have been compared with the most significant variable of spent-fuel storage — its capacity.

Investment costs. The different total investment costs have been discounted to values in a common year, 1988, employing the same discount rate whenever possible, and they have been plotted versus the store capacity. The investment costs are given in millions of US dollars and the capacity in metric tonnes of uranium. In spite of the great uncertainties and differences in the considered cases, all the discounted investment costs fall into a specific area. *(See above graph.)*

Two straight lines limit this area. The upper bound corresponds to metallic casks and the lower bound to storage pools at-reactors (AR) and dry wells. Although both lines do not have any specific economic meaning, these could be associated to maximum-minimum investment costs for a given storage capacity.

Operating costs. They are usually incurred after the construction and commissioning of the facility. Payments made before the storage of the fuel are mainly of fuel transfer from the nuclear power plant to the facility. Payments during the storage of the fuel are due to the components mentioned above. At the end of the lifetime of the storage facility, new fuel transfer costs must be made for the fuel's ultimate handling (reprocessing or disposal).

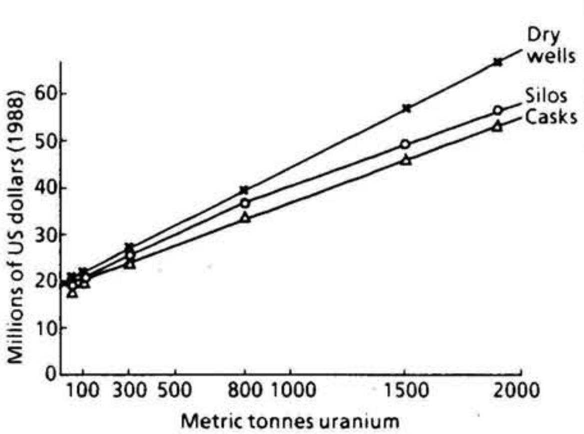
After these final fuel transfers, the facility must be decommissioned and in some cases these decommissioning costs are included in the operating cost.

The capacity of the storage facility is a very important factor in the operating costs. The option selected for storing is also a decisive factor in the operating costs.

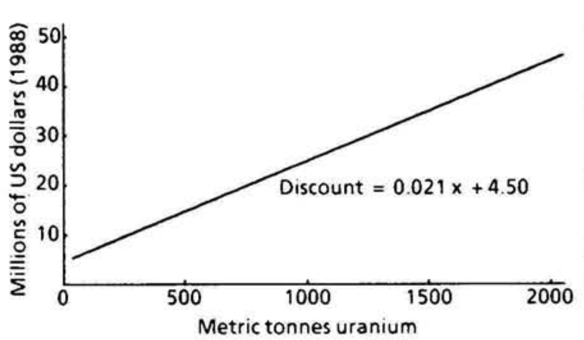
The operating costs of all the cases studied have been correlated with the capacity. These costs are the annual operating costs discounted to the year 1988 and added during all the years of the plant's lifetime to obtain the total operating costs. To calculate the specific operating costs, it is necessary to divide them by the capacity of the storage, or much more appropriately, to lèvelize these costs. *(See graph on page 36, top.)* When this is done, the highest values belong to dry wells and the lowest to cask types of storage modules.

Decommissioning costs. This category of costs is usually made at the end of the lifetime of the facility and can vary according to the storage capacity and the form of decommissioning: immediate dismantling, mothballing, or entombment.

Total operating costs versus capacity



Decommissioning costs versus capacity



Decommissioning costs, even though they may be substantial, contribute very little to discounted total costs — because they involve amounts of money to be spent many years after the facility starts up — if the real interest rate is used in the calculations. However, it is advisable to compare these costs without discounting. They vary with the size of the facility and clearly follow a linear equation. *(See graph below left.)*

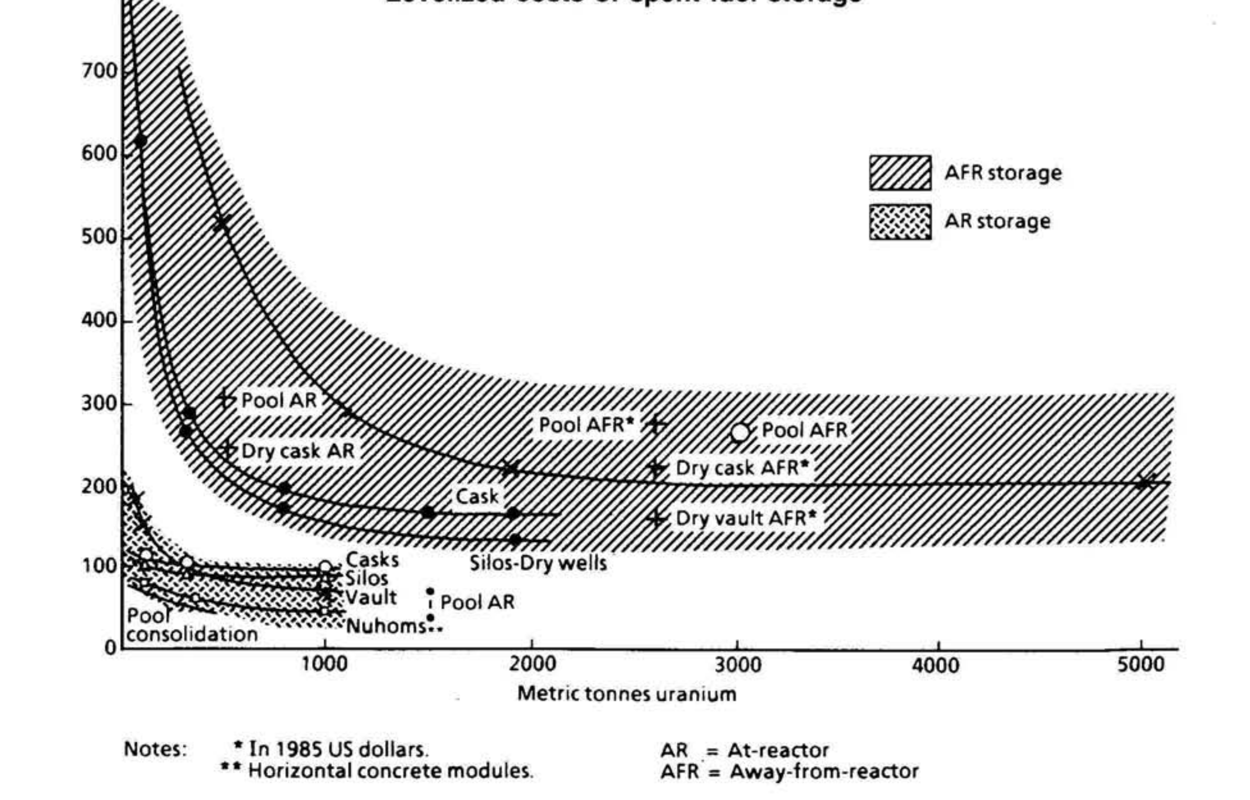
Levelized costs

Up to now, reference has been made to costs and the NPV of costs. Whenever these costs must be recovered by income, which is true in the case of spent-fuel storage, the NPV of income over the recovery period should equal the NPV of costs.

The income may be generated in many ways: use of pre-payments, annual charges, or payments on delivery. For each method of payment, an NPV of revenue must be derived and equalized to the NPV of costs. Then a levelized unit cost (LUC) can be defined.

To the general uncertainties affecting the estimates of the different cost categories, in order to reach some viability in the correlation of levelized unit cost, it is important to note that: (1) the LUC must be expressed, in all cases, in money of the same year, in this case 1988; (2) for a given storage capacity, the loading rates, in metric tonnes of uranium per year, must be very similar to each other; and (3) the discount rate used in calculating the LUC must be also the same in all cases.

Levelized costs of spent-fuel storage



Notes: * In 1985 US dollars.
** Horizontal concrete modules.

AR = At-reactor
AFR = Away-from-reactor

In this article's analysis, the LUC of different cases, recorded and processed from the many references studied, were correlated versus the storage capacity. Both wet and dry storage methods were considered, as were certain other variables, such as discount rate, loading rate, and facility lifetime. *(See graph on page 36, bottom.)*

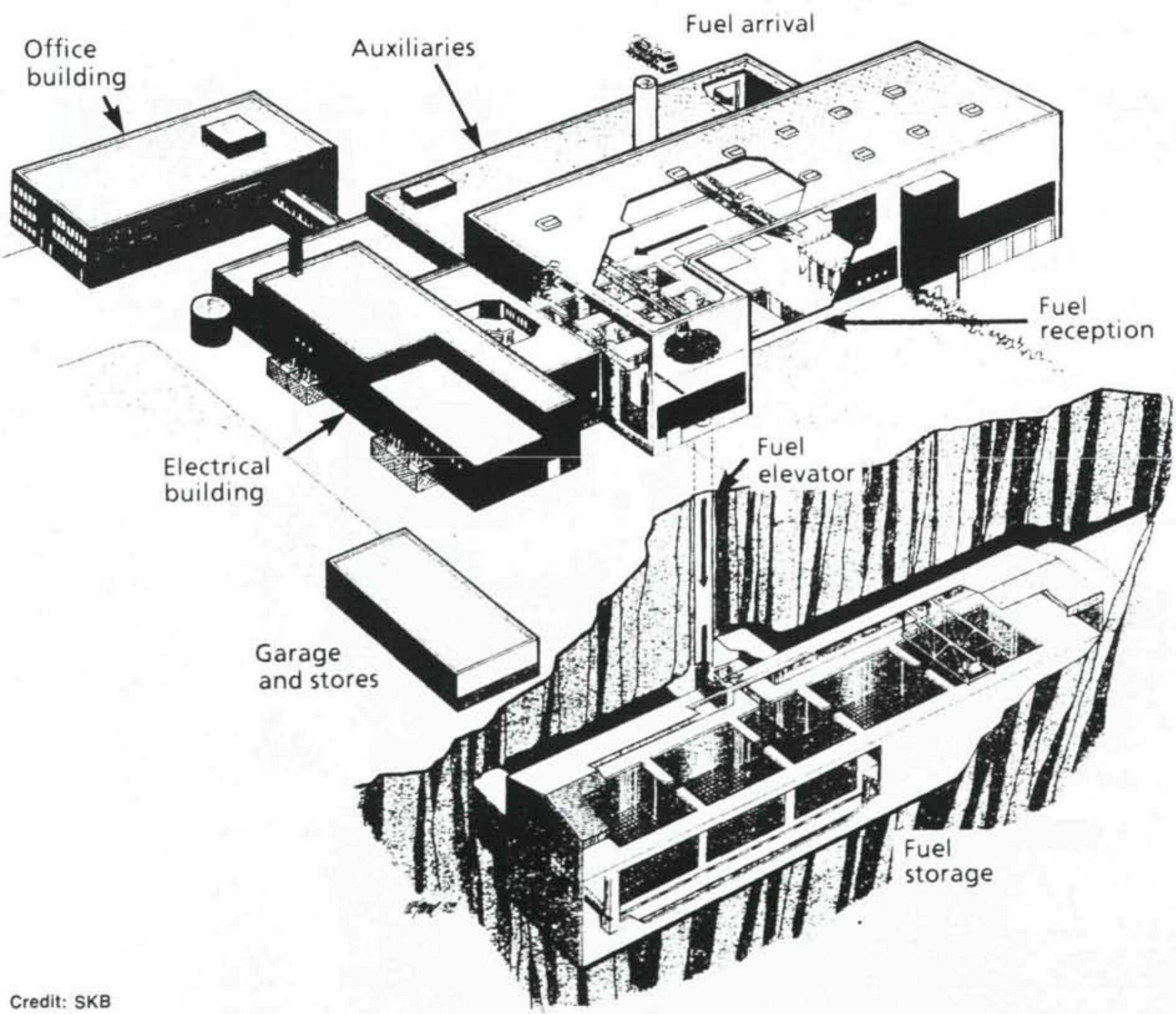
Financing

There are different possibilities for financing the selected option for spent-fuel storage. The financing method chosen has to take into account all the payments that must be made during the construction, operation, and decommissioning periods of the storage facility, and also the way in which the facility's owner will obtain the money.

The different methods of funding take into account the different types of storage facility ownership (for example, the utility alone or an independent service organization). In the first case, the storage capacity extension may be financed in a way similar to the construction and operation of the power station, recovering the costs from consumers through the price of electricity. Management of this cost recovery fund varies from country to country.

The case is a little different when the storage facility is owned and operated by an independent organization. The organization can ask for payments by means of a contractual commitment, including fees and/or advanced payments to cover costs supervised by the Government. The Government could even legally require the establishment of a special fund to cover the storage and subsequent final management costs.

Schematic of the waste disposal system in Sweden for underground disposal of reactor wastes and storage of spent fuel



Credit: SKB

Conclusions

From the concepts included in this article, two types of conclusions can be drawn. Each should be helpful in a decision-making process.

General conclusions are:

● The selection of the at-reactor (AR) or away-from-reactor (AFR) storage option must be made from purely strategic considerations, taking into account the nuclear power programme of each country.

● For capacities below 300 metric tonnes uranium, the AFR option is not convenient because the cost is very high, above US $300 per kilogram uranium (in countries with a small nuclear programme).

● For capacities over 1000 metric tonnes uranium, the AR option may not be adequate (in countries with a large nuclear power programme).

● The AR option has lower costs than the AFR one. However, other needs of storing spent fuel must necessarily also be considered.

Specific conclusions are:

● The consolidation of fuel in existing pools (after reracking and double tiering) is the cheapest solution in the AR option but has a short capacity limit (under 300 metric tonnes uranium). It has to be kept in mind that the reactor pools are for the support of the reactor operation and not to store important quantities of spent fuel during long periods.

● In the AFR option, the wet storage technologies present higher costs than the dry storage solutions.

● The dry storage solutions offer a modular approach that has a positive effect on financing costs.

A spent-fuel cask being handled in the receiving hall of the spent-fuel storage facility in Sweden. (Credit: CLAB)