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On the Commercial Feasibility of Decommissioning a Nuclear Power Plant Ship

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1. Introduction

Environmentalists have challenged the continued use of conventional sources of fuels and power in recent years because of their polluting nature. For human health and safety, it is essential to maintain and improve the environment. Increased energy use and a clean environment need to be mutually exclusive. Although nuclear plants do not produce pollutants in their normal operating cycle, the operation of nuclear plants will have some interactions with the environment that should be quantified and evaluated.
The economic contribution that nuclear energy will make to the solution of the nation's energy problems depends on its perceived merits relative to existing and alternative sources of energy and fuels.
Its commercial development will depend finally on political and other factors that cannot be assessed quantitatively. The national security and environmental impacts of continuing dependence on oil should receive major emphasis in decisions to implement new process for fuel production.
Actual manufacturing costs are generally unavailable and are highly dependent on the financing methods and resources of the individual producer.
The use of nuclear energy would be a feasible option to reduce the greenhouse gases emission by merchant ships; however, decommissioning brings high costs, which affect the economic feasibility. Therefore, it is important to develop a good recycling policy after deactivation of a ship with nuclear-power propulsion. Still, there are additional costs in the project whose estimate is, sometimes, difficult to obtain.
Reactor types and sizes, the number of reactors on an individual plant site, and labour costs are among the main factors affecting costs. Experience shows, except after major catastrophic accidents, nuclear industry may earn public trust by open dialogue with the population and sound engineering practices, searching for right technical solution and great planning for long time.
The Center for Nuclear Waste Regulatory Analyses (CNWRA) and its expertise and experience in the nuclear fuel cycle, particularly from the regulatory perspective are generally familiar with Brazilian Authority CNEN (Comissão Nacional de Energia Nuclear) and its important work in ensuring the safety of nuclear power production and waste management [1].
They have seen the recent announcement of Electronuclear's teaming with Westinghouse for support on the long-term operations program for the Angra-1 (Brazilian nuclear reactor), and they are aware of the on-going licensing of a dry storage facility for used nuclear fuel.
Within this context, the CNWRA wanted to be sure that everybody is aware of its expertise and experience in nuclear facility safety and radioactive waste management. If needed, the highly skilled staff members are available to augment any teams in addressing nuclear safety programs in Brazil. While they have experience applicable to many areas of nuclear safety regulation, they wish to draw their attention in particular to aging management of nuclear power plants and used nuclear fuel storage facilities.
For the US Nuclear Regulatory Commission (NRC), CNWRA was the primary source of technical assistance and evaluations supporting production and publication of the Subsequent License Renewal (SLR) Generic Aging Lessons Learned (GALL-SLR) and Standard Review Plan (SRP-SLR) NUREGs. These documents are detailed, comprehensive guides for evaluating long-term aging management of nuclear power plant components when operators are applying to extend their licenses beyond 60 years (typical nuclear power plant ships in Brazil). For used nuclear fuel storage, they have performed numerous research studies on monitoring and long-term performance of storage system components and assisted NRC in the production of a major document on aging management [2].

2. Methodology

2.1. Factors that determine the commercial viability

Nuclear Energy Institute searched for to estimate the costs for main reactors type decommissioning. It is important to highlight that decommissioning cost for a nuclear power plant onshore does not bring direct impact to plant capacity, i.e., the fixed cost as safety, protection, project management and waste management are relatively more expensive for little and medium nuclear power plants. Pressurized Water Reactor costs are estimated between US$ 200/kW and US$ 500/kW. The Table I show the economic-technical-parameters for nuclear thermoelectric.

Table I: Economic-technical-parameters for nuclear thermoelectric [3]

Investment Cost (US$/kW)	5000
Operation and Maintenance Cost (US$/MWh/year)	110
Fuel Cost (US$/kW)	9
Useful Life cycle (years)	60
Construction Time (%)	7
Efficiency (%)	33
Nuclear Power (MW)	1000
Medium capacity Factor (%)	85
Decommissioning cost (US$/kW)	200 to 500

The basis of most engineering decisions is economic. Designing and building a device or system that functions properly is only part of the engineer’s task. The device or system must, in addition, be economic, which means that the investment must show an adequate return. In the study of thermal systems, one of the key ingredients is optimization, and the function that is most frequently optimized is the potential profit. Sometimes the designer seeks the solution having minimum first cost or, more frequently, the minimum total lifetime cost of the facility. Estimated costs of 1000-MWe nuclear power plants, based on estimated costs per kilowatt, are as follows in Table II:

Table II: Nuclear Steam Electric Power Plants (1000 MWe) [4]

Plant investment	$1700-3000M
Fuel cost/year	$32M
Operating and maintenance cost/year	$42M
Delivery cost/year	$37M

Actually, there is almost nothing from experience taking into account commercial nuclear reactors decommissioning and due to that, an inadequate base for final decommissioning costs. A typical hypothesis would be a decommissioning cost from 9% to 15% from the initial cost capital of nuclear power plant.

Both, decommissioning and handling with radioactive waste are so expensive process, but due to the future cost, any discount cost, for any discount tax, it will be almost nothing.
This is ignored in the present financial analysis because of the wide spread in the estimates of the plant investment. In addition, the costs of nuclear waste disposal are not included. No firm solution to this problem has been found, but programs seeking a solution were funded at $800M/year. If prorated among the operating costs of the present nuclear plants, this would add approximately $8M/year to the operating costs of the typical plant.
Thus, it is so important to develop a good recycling policy after nuclear-power plant ship inactivation. This work found that adequate requirements identification must keep economics aspects always in the centre of design. The decommissioning cost is important searching for an economy.
Decommissioning costs are so high for nuclear power plants because are technically complex and must satisfy strict licensing and design requirements. The design and construction of a new nuclear power plant requires many highly qualified specialists and often takes many years, compounding financing costs, which can become significant.
Overnight cost is the cost of a construction project if no interest was incurred during construction, as if the project was completed overnight. Overnight costs exclude interest accrued during plant construction and development.
According to a subsequent revision of the Ordinance on the Decommissioning and Waste Management Funds for Nuclear Facilities in Switzerland, a contingency of 30% of the overall overnight cost should be taken into account for determining the provisions for the decommissioning and waste management funds in the future.

2.2. **Evaluating potential investment**

This includes cost of related facilities as well as the plant investment. An important function of economic analyses in engineering enterprises is to evaluate proposed investments. A commercial firm must develop a rate of return on its investment that is sufficient to pay corporation taxes and still leave enough to pay interest on the bonds or dividends on the stock that provide the investment capital. The evaluations can become very intricate, and only the basic investment situations will be explained. This fundamental approach is, however, the starting point from which modifications and refinements can be made in more complicated situations.
Four elements will be considered in investment analyses: (1) first cost, (2) income, (3) operating expense, and (4) salvage value. The rate of return is treated as though it were interest.

3. Results and Discussion

Since construction costs are reduced as component size and numbers increase, it is desirable to estimate projected product prices based on the same total output for each system compared. The number of modules needed to generate the desired electric power output is shown in column 8, the sales price of electricity in column 9, and the total investment in column 10.

Table III: Alternative electricity sources price comparison [5]

(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Fuel	Fuel cost ($/GJ)	Plant investment ($M)	Output (kWh/y)	Annual cost ($M/y)	Break-even sales price ($/kWh)	Number of modules for 10^{10} kWh/y	Sales price ($/kWh)	Investment for 10^{10} kWh/y ($B)
Uranium	7.0	2350	5.3x10	84.0	0.069	2	0.063	4.5

4. Conclusions

Another important subject to point out takes into nuclear ships account the crew reduction due to on board automation. As assumption, regarding similar proportion, it brings an economy for proposal requirements, which it almost of them decrease the cost.

Any nuclear power plant with everything accessible would be faster for decommissioning rather than anyone without any careful. Any nuclear power plant ship without activated material (steel without cobalt) would be easier to recycle and faster for dismantling, once the operators do not need different watches due to dose rate. Without different watches, the workload could be reduced at least a half from the previous schedule.

It is important to highlight that a financial analyses for decommissioning cost reduction in case to raise budget during the nuclear power plant life cycle in order to achieve the decommissioning versus the decommissioning overnight cost. A cost comparison is absolutely different when to compare between nuclear power plant for 30 years life cycle and 60 years life cycle. There are three critical parameters that are responsible for nuclear energy economy; overnight construction cost (OCC), construction period and reduction tax.

Given that the decommissioning process may take several decades, it is important that plans are defined in advance. Greater funding and international cooperation are required to share information and expertise on the decommissioning.

Decommissioning of nuclear power plant ships will cause costs to grow continuously and will cause environmental problems for the years to come. The magnitude of the problem is not really known to the broader public.

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