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Review

Modern financial models of nuclear power plants

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ABSTRACT

The last few years have seen some significant changes in the financing of large infrastructure projects, including nuclear power plants. Financial models must take into account factors such as high capital investment, long construction periods, long capital payback periods, problems associated with the fuel cycle, including security of supply, exchange and storage of fuel, non-proliferation. Traditionally, the only entities facing the difficulties and risks mentioned above were large, vertically integrated, state-owned or regulated, sovereign-backed utilities. Also, only they have been able and willing to undertake the financing of investments. The change consists in a greater interest in global capital markets in order to diversify sources of financing and to spread both the costs and the risks among numerous groups of investors. The evolution of the financial models of nuclear power plants in the world takes place based on the following trend: government financing, corporate financing, hybrid financing, project finance. This transformation is moving towards a greater involvement of private capital instead of a reduction of the share in public funds. The article is a detailed discussion of a few modern financial models: Government-to-Government Financing, Loan Guarantees, Host Government-Backed Power Purchase Agreement (PPA), Vendor Financing, and Investor Financing.

1. Introduction

One may find many similarities between investments in nuclear power and other significant infrastructural investments. These include high capital intensity, long lead times, long payback periods. Typical problems for the type of investments are mainly related to the fuel cycle. Some of them would be: security of supply, used fuel and waste management as well as non-proliferation and decommissioning. The operator would be responsible for the nuclear liability and ensuring safety in case of extraordinary nuclear events. Due to strong regulation in the power industry, there is a high risk of some uncertainty occurring in the regulatory process.

Over the last sixty years, typical economic studies of nuclear investment have shown an unusual sensitivity to changes in its parameters, including those with an unpredictable fluctuation in time. Some of them would be the wholesale price of energy or the authorisation price for the emission of carbon dioxide granted as obligatory by the European Commission. The volatile nature may be observed throughout the whole energy market. The economic downturn has caused a decrease in energy demand, so new generation capacities are not required.

The bigger the capital expenditures, the more important the financial model. Attracting tens of billions of euros for the construction of a large nuclear power plant is a difficult task. Such an investment is not only very costly in terms of initial investment, but also involves a considerable risk, which further increases the cost of the invested capital. The capital expenditures vary between the different regions of the world and include the following limits (World Nuclear News, 2014):

- Europe 1900–7200 USD/kW,
- North America 2400–7000 USD/kW,
- Middle East 3240–5300 USD/kW,
- Rest of Asia 1600–4365 USD/kW.

The above costs also depend on the specific location of the object, its size or technology. The choice of first-of-a-kind technology may result in a project's overnight capital cost increasing by up to 30% (World Nuclear News, 2014). However, it seems extremely difficult to predict the future costs of construction and use of nuclear power plants. Observations have indicated that there is no clear trend of costs, while indicating the dependence of costs on many factors including the location of the investment, the legal regime or international cooperation in the project. Implementing projects of similar scale and technology at the same time, but in different places in the world can generate differentiated costs (Lovering et al., 2016).

A significant problem is the construction risk. In order to earn the investors' trust, more blocks need to be built within the prescribed time

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and budget, as with the Chinese Ningde 2 and Honhgyanhe 1 and 2. Unfortunately, there are now many more examples of negative growth in construction time and effort than originally planned. Some of them include Olkiluoto 3, Flamanville 3, Levy County, Angra 3, the Watts Bar 2, Taishan 1 and 2 and Hongyanhe. Nadira Barkatullah, PhD, Director of Economic Regulation at the Regulation and Supervision Bureau of the United Arab Emirates, says that in North America, with a two-year delay and the discount rate at 10%, the overnight costs of construction could rise by 75% (World Nuclear News, 2014).

The average construction time for completed power plants in 2015 was 73 months, compared to 127 months in 2014. The average for 2011–2015 was 66.4 months (World Nuclear Association, 2016).

Numerous studies of the costs of generating electricity from nuclear sources have been published in recent years. Among the most accurate publications in their methodological approaches and data, we can mention: "The Future of Nuclear Power" (Massachusetts Institute of Technology, 2003) and its recent update "Update of the MIT 2003" (Massachusetts Institute of Technology, 2009), published in 2009 as a result of the sharp increase in the cost of raw materials and generation technologies which occurred between 2004 and 2008. Several institutions in the USA have provided detailed technical studies of the same subject, including "The Economic Future of Nuclear Power" (University of Chicago, 2004) and "Nuclear Power's Role in Generating Electricity" by the Congressional Budget Office (Congressional Budget Office, 2008). Furthermore, for the sake of completeness of the analysis, what deserves a mention is the study "Levelised Unit Electricity Cost Comparison of Alternate Technologies for Baseload Generation in Ontario" and the detailed study "Nuclear Feasibility" (Wilson, 2009), where special modeling software along with levelised cost analysis of electricity equations are used to analyse the technology under different scenarios.

This article attempts to identify the modern models of financing new nuclear power plants, which make an effort to deal with the aforementioned difficulties.

2. Economic efficiency assessment methodology

We can find various methods for determining the economic efficiency of power plants. One of them is the Net Present Value method. It is calculated as the sum of the discounted differences between cash inflow and cash outflow, realised throughout the lifetime of the power plant, separately for each year. The value of this sum expresses the profit which the development of the project can bring the investor.

The discounting can be carried out for any time, but usually coincides with the planned facility construction start time. The discount rate should be defined based on certain rules. It can be interpreted as the rate of profit, below which the investment does not pay off (i.e. the minimum rate of efficiency).

Net present value is calculated using the following formula:

$$NPV = \sum_{t=1}^{n} (CI_t - CO_t) = \sum_{t=1}^{n} \frac{NCF_t}{(1+p)^t a_t} \quad (1)$$

where:

NPV – net present value; NCF_t – net cash flow in year t; n – the discounting period (facility life-cycle); CI_t – cash inflows in year t; CO_t – cash outflows in year t; p – the discount rate.

A positive NPV value is a prerequisite for the profitability of a project. The boundary of profitability is NPV = 0. A project which yields the highest net present value should be selected.

Another method consists in determining the long-term unit cost of generating electricity. It refers to the NPV, as well as taking into account the changing value of money over time. In the formula, the discount factor is present not only for the cash flow but for the volume of energy as well. The energy is treated as a result of the production and is discounted using the same method as for costs incurred in subsequent years.

The expanded formula for long-term unit cost of production in facilities designed takes the following form (Paska et al., 2010; Paska, 2012):

$$k_j = LCOE = \frac{\sum_{t=1}^{n} I_t \cdot (1+p)^{-t} a_t + \sum_{t=10}^{n} K_t \cdot (1+p)^{-t} a_t - WM_n \cdot (1+p)^{-n} a_n}{\sum_{t=10}^{n} A_t \cdot (1+p)^{-t} a_t}, \quad (2)$$

where:

LCOE – levelised cost of energy; n – the period of analysis, covering the period of construction and operation of the facility; I_t – investment in year t of analysis; K_t - costs of operation of the facility in year t; WM_n – the value of non-amortized assets in the n-th year of operation (final value of the assets); A_t – energy produced in year t.

3. Financial models

3.1. General trends

Traditionally, the only entities which, against the difficulties and risks mentioned above, have been able and willing to undertake the financing of investment, have been large, vertically integrated, sovereign-backed utilities. As noted by Nadira Barkatullah, in this situation, the costs associated with such a model of financing and all the risk associated with it focus on electricity consumers (Barkatullah, 2011). The utilities are covered from the consumers' taxes, as well as the fees they incur for energy.

However, as in the case of large capital-intensive power infrastructure projects in other sectors, the financing of nuclear power stations over the last decade has changed significantly. Investors with interest take advantage of global capital markets in order to diversify the sources of finance and spread the financial cost and risk among multiple investors. These changes are presented in Fig. 1.

As Daniel Joyner noted (Joyner, 2014), although there are many types of financial structures, there are essentially two sources of capital: equity or debt. Typically, infrastructure projects combine both these sources to varying degrees. According to Nadira Barkatullah, there are three possibilities (World Nuclear News, 2014):

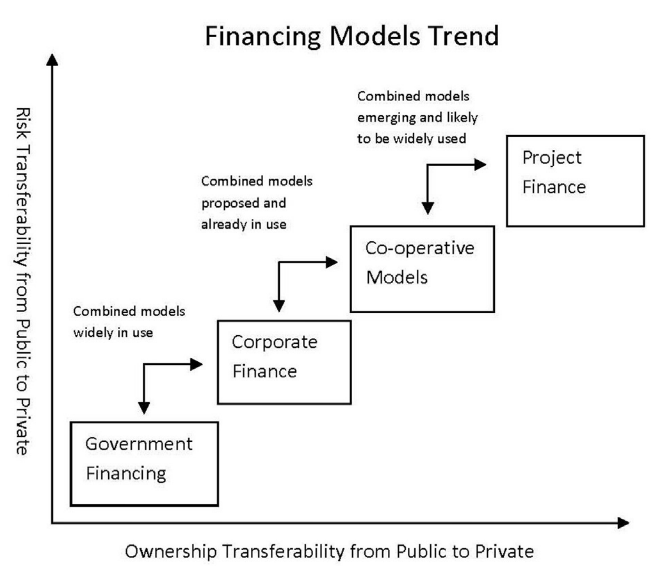

Fig. 1. The transformation of the investment financing scheme between the public and private sectors (Barkatullah, 2011).

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