ARTYKUŁY

THE COST OF NEW NUCLEAR IN FRANCE

Koszt nowej energetyki jądrowej we Francji

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Abstract: The French Nuclear Society presents the main points of nuclear program in France until 2050 based on III generation reactors. The development will be based on replacement of existing reactors by new EPR reactors. During the implementation of the program the experience gained in the recent construction and putting into operation of such blocks in the world (e.g. in Finland, France and China) will be used, which would lead to reduction of investment cost.

Streszczenie: Francuskie Stowarzyszenie Energii Nuklearnej (SFEN) przedstawia wizję rozwoju programu energetyki jądrowej we Francji do 2050 r. w oparciu o reaktory III generacji. Zachodzące zmiany polegać będą na zastępowaniu istniejących bloków przez reaktory EPR. Przy jego realizacji będzie wykorzystane doświadczenie z obecnie budowanych i uruchamianych bloków EPR na świecie (Finlandia, Francja i Chiny) co pozwoli to na redukcję kosztów inwestycyjnych.

Słowa kluczowe: SFEN, III generacja reaktorów jądrowych, EPR, Francja

Keywords: SFEN, III generation of nuclear reactors, EPR, France

Guaranteeing the nuclear option for 2050

With its June 2017 Climate Change Plan (*Plan Climat*), France has set a greenhouse gas emissions neutrality target for 2050.

France currently relies on nuclear and renewable energy for generating low-carbon electricity, with one of the most competitive supplies in Europe.

France is committed to diversifying its energy mix at a pace that will depend on several factors which are not yet fully clear: the characteristics of demand, the technical and economic performance of the different technologies (renewable energy, storage, smart grids), as well as the energy strategies of its European neighbours, as part of an increasingly interconnected electricity system.

In the short-term, continued operation of existing nuclear reactors ('*Grand carénage*' refurbishment programme) will provide France with low-carbon electricity, produced locally and at a competitive price.

In the long-term, between 2030 and 2050, France is expected to progressively replace part of its existing nuclear fleet by new means of production. While technical and economic progress is expected, significant uncertainties remain concerning the feasibility, reliability and cost, as well as the specific limits of a system that is heavily, possibly exclusively, reliant on intermittent renewable energy coupled with storage, biogas, and/or fossil fuels with carbon capture and storage.

Given the uncertainties and the urgent need to significantly and rapidly reduce global CO_2 emissions, the International Energy Agency[1] states that nuclear energy is indispensable, and complementary to the development of renewable energy, for a CO_2-free energy mix. This should in all likelihood be the case for France, which is a world reference for use of and industrial expertise in this technology.

In order to avoid significant climate (maintaining or opening new fossil fuel plants, resulting in increased CO_2 emissions) and economic (increased electricity production costs) risks, France must consider the option of replacing part of its nuclear fleet by EPR-type third generation reactors.

In recent years, the first third generation reactor projects have encountered issues during construction. However, it is important not to allow initial cost overruns to overshadow two key considerations. Firstly, these issues have been overcome and the first EPR will be connected to the grid in the next few months. Most importantly, these projects have revived the French and European supply chains, which are now ready to build new units. The nuclear sector, the third industrial sector in France with 2,500 companies and 220,000 highly qualified professionals, has the right tools to succeed.

1. The first third generation reactor projects have encountered challenges inherent to new projects. France has overcome these and now has a revitalised and operational supply chain ready to build new EPR.

A review of the First-of-a-Kind (FOAK) third generation reactor projects shows that they have overrun their initial budgets.

This situation is common to complex large infrastructure projects, an example being the

[1] IEA ETP 2017 Report, 2DS and B2DS Scenarios.

Channel Tunnel whose final budget was double the initial estimate. Numerous studies make reference to 'optimism bias'[2] in project forecasts prior to launch. They also draw attention to phases of 'rapid learning' in subsequent projects[3].

This technical note highlights the significant differences between third generation reactor projects in the following countries:

- Countries that are actively building a series of reactors, either because they are extending their nuclear build programme (China), or because they are replacing part of their fleet (Russia). Indeed, it is of note that the first third generation reactor to go online was in Russia, and the first EPR to startup will be Taishan 1, in China.
- Countries that had stopped building reactors (France, Finland, United States). These countries have been doubly disadvantaged, both by uncertainties associated with FOAK projects and having to upgrade their supply chain to the standards required for Gen-III reactors.

Having overcome these issues, the first units are now in the startup phase, and France once again has a supply chain capable of building new reactors (large components, expertise, professional skills, industrial equipment, research capabilities). There is a risk that the returns on this investment will be lost should France once again stop building reactors at home.

2. Construction costs are the main contributing factor to overall production costs of a nuclear reactor. These costs can be controlled, provided that France commits to an industrial programme.

The cost of a nuclear reactor is in large part dominated by investment costs in the construction phase which, depending on the discount rate used, represents between 50% and 75% of the total electricity production cost over the facility's operating period.

A review of the first French programme, and other countries' programmes, clearly demonstrates that construction costs can be reduced. This requires development of an industrial programme which generates an economic series effect, and integrates lessons learned from previous construction projects, as well as the latest innovations.

- **Taking advantage of the economic series effect**

The economic series effect refers to the fact that the average investment cost for a series of standard units is less than that for a single unit of the same type, designed and produced separately.

This primarily requires systematic construction of pairs of reactors on the same site, resulting in benefits from several combined effects:

- **'Programme' effects**: assessments and qualifications will be valid for a large number of units.
- **'Productivity' effects**: suppliers can make productivity gains when producing a series of identical items, which they can reflect in their prices.
- **'Pace' effects**: the number of units ordered must ensure a continuous minimum volume for all industrial stakeholders, from design studies to manufacturing, this being achievable through correct management of project costs, lead-times and processes.

Making use of learning-by-doing effects and the latest innovations

- **Improving design**: sharing of lessons learned from Olkiluoto 3 (Finland) and Flamanville 3 (France) has already been of benefit to the Taishan 1 & 2 project (China). The process of EPR design optimisation adopted in 2015 has also led to a simpler design, improving ease of construction and industrial-scale component production.
- **Using the latest methods and techniques**: several innovations have improved performance. Examples include reinforced concrete, 'modularisation' of specific parts of a plant, and the use of engineering methods to improve communication between the different parties involved in a project.
- **Revitalising Europe's supply chain**: the nuclear sector has strict requirements in terms of quality assurance, material purity, component behaviour under irradiation, long-term wear, etc. The whole European supply chain[4] had to be qualified to a 'nuclear quality' level for construction of the Olkiluoto 3 and Flamanville 3 EPR. Future projects will benefit from this restored supply chain, resulting in reduced costs.

Combining these measures will lead to improved project and lead-time management, a key component of economic efficiency.

There are several expected outcomes:

- Time savings by project teams.
- Reduced fixed construction costs.
- Reduced financial costs related to interest over the construction period (as it is shorter).
- Earlier electricity production (which greatly increases the value of the project).

3. Project financing and expected returns on investment have a major impact on the cost of a project. The State has a key role to play. France can learn from discussions in the UK.

[2] Working Paper on Risks n°52, *A risk management approach to a successful infrastructure project.* See also, E. M. Merrow, P. E. Phillips, and C. W. Meyers, *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants,* Santa Monica, CA: Rand Corporation, 1981.

[3] PWP Ltd., *Pelamis: experience from concept to connection*, *Phil. Trans. R. Soc. A* (2012) 370, 365–380.

[4] The European supply chain involves several hundred companies distributed across 10 countries.

Private investors expect a return on investment for nuclear projects of the order of 9% to 10% in terms of WACC[5]. In addition to the risks associated with the project, these rates reflect market risks (changes in average electricity price), political risks (project called into question by a change of government) and risks related to regulatory changes, which are likely to result in increased costs and project lead-time.

The State's interest in nuclear projects is twofold, as they must ensure the security of electricity supply whilst also reducing CO_2 emissions. In light of this dual objective, new nuclear power plants, as well as existing ones, represent strategic infrastructures, which help to ensure the security of electricity supply and provide low-carbon energy. The State can play a key role in 'removing' project risks or in spreading risks among stakeholders.

In relation to this last point, several lines of approach are possible:

- **Reduce market risks**: the average price per kilowatt hour on the European wholesale market has been halved in the last decade. Many stakeholders are dissatisfied with the current market set up, which does not favour low-carbon energy sources, and are calling for improved visibility for investments. The CFD (*Contracts for Difference*) mechanism used in the United Kingdom attracts investors by guaranteeing returns on investment, for renewable energies and nuclear, based on the services provided.
- **Spread risks more evenly among stakeholders**: a recent report by the UK's National Audit Office[6] draws attention to the considerable sensitivity of electricity prices to the expected rate of return for a project, which is directly linked to contractual arrangements between private investors (high returns), suppliers (high profits) and the State (low returns, owing to longer term objectives, and risk mitigation through investment in several different large projects). For example, the cost of a kilowatt hour for Hinkley Point C (UK) doubles when the discount rate changes from 3% to 10% (value close to EDF's cost of capital for the project).

RECOMMENDATIONS: Review the supply chain and financing mechanisms for reducing the cost of third generation nuclear power

The cost of third generation nuclear power is based on two factors: construction costs and financing costs. The SFEN has estimated that significant savings are possible compared to the first projects: of the order of 30% on construction costs, due to economic series and learning-by-doing effects, and up to 50% on financial costs, particularly in contractual arrangements.

There are numerous ongoing projects looking to make the most of these savings and ensure that third generation nuclear is one of the most competitive sources of dispatchable generation. This would mean a cost at the lower end of that for combined-cycle gas power plants with a carbon price (of the order of €20-30/tCO_2).

The State has a role to play

The SFEN suggests engaging with public bodies in a review of the supply chain and financing mechanisms for reducing the cost of third generation nuclear power. A key factor is optimising the allocation of roles amongst the public bodies and the industrial players involved in implementing a project. It falls on the State, which guarantees national strategic interests, to maintain a baseline supply of decarbonised electricity, which is flexible, competitive and predictable, up to 2050.

Timescale

This review must be completed without delay before 2020, in order to meet the objective of getting the first pair of reactors online by 2030. The first pair will be part of an industrial programme for a series of EPR, for which lessons learned will contribute to the designs of at least another three pairs of reactors.

Expected benefits

Using this industrial programme approach will provide the whole supply chain, from large groups to small and medium-sized enterprises (SME), with the visibility and timescales required for investing in production lines and competences, as well as for taking advantage of the series effect right from the first construction projects. This industrial programme will enable France to keep the nuclear option open, for managing the decarbonisation of its economy and the renewal of its electricity mix by 2050.

Consequences of not taking action

Without this, France will lose control over strategic components of its reactors, for which relying on a foreign supply (from China or Russia) would represent a major economic and geopolitical concern and, no doubt, a permanent loss of technological and energy sovereignty.

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5 WACC: *Weighted Average Cost of Capital.*

6 Department for Business, Energy & Industrial Strategy, *Hinkley Point C*, National Audit Office, HC 40 SESSION 2017-18, 23 JUNE 2017.