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Nuclear New Build: Insights into Financing and Project Management

Executive Summary

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Executive summary

Nuclear new build has been steadily progressing since the year 2000, with the construction of 94 new reactors initiated and 56 completed reactors connected to the grid. Among these new reactors are some of the first generation III/III+ reactors of their kind. This period has been one of technological, structural and geographical change, and the experiences gained since the beginning of the 21st century, as well as the challenges that projects have faced and the solutions sought to overcome these challenges, have been gathered in this report to provide a valuable reference for policy makers and stakeholders concerned with nuclear new build. The report offers an authoritative overview of global trends in nuclear power plant (NPP) construction over the past two decades. The challenge of constructing NPPs is analysed from two principal perspectives: first, from the importance of revenue stability over time for high fixed cost projects; and second, from the potential for improvements in efficiency through the optimisation of project and supply chain management.

The report provides a snapshot of the current state of affairs in nuclear new build, demonstrating that today 68 nuclear reactors are under construction, while a further 159 projects are planned. The largest single market is that of the Peoples' Republic of China, with 27 reactors under construction and 56 reactors planned. These numbers should be compared to the current operating fleet of 435 reactors worldwide. While a majority of the reactors under construction remain generation II designs, an increasing number of new build projects concern generation III/III+ reactors. Due to first-of-a-kind (FOAK) issues, generation III/III+ projects can undergo experiences not encountered in other construction projects. At the same time, there is considerable potential to learn from such FOAK projects, and to decrease costs and the duration of construction.

The importance of electricity prices and revenue stability

The second part of the report focuses on the first of two key issues for successful nuclear new build (NNB), the importance of the long-term stability of electricity prices in order to ensure revenue stability and the financing of NNB projects. Based on the results of an economic model where different power generation technologies compete according to their variable costs in a market with daily dispatch, the present report shows that the high fixed costs of nuclear power make it more vulnerable than other dispatchable technologies such as gas to declines in average electricity prices. These price declines are far from a theoretical possibility. In Europe, for example, wholesale electricity prices are today more than one third lower than in 2007 with no perspective of an increase in the coming years. In uncertain markets, a gas-fired power plant, with its lower fixed costs, is exposed to considerably lower financial risks than a nuclear plant, even if both plants have comparable levelised costs of electricity (LCOE) over their operating lifetimes.

At the date of commissioning, investors in a gas plant commit a smaller portion of total lifetime costs in an irreversible manner than investors in a nuclear plant. In the case of a long-term decline in power prices, the gas plant can limit its losses by shutting down and temporarily or permanently leaving the market. The nuclear plant does not have this option, since up to 80% of its total lifetime costs have been irreversibly committed the day of commissioning. Long-term electricity price risk is thus a major deterrent against investment in nuclear power.

Experts and investors in nuclear power, as well as governments, normally have at least an intuitive understanding of this issue. However, the report shows that the differences in the net present value (NPV) of a nuclear plant and a gas plant, which have the same LCOE under price certainty, are significant in the presence of possible long-term declines in wholesale electricity prices. For a permanent 30% fall in electricity prices, the difference amounts to USD 1 billion, and this sum rises exponentially for larger price falls. Results such as these should be sufficient motivation to accelerate the search for economically efficient measures capable of reducing the gap in risk exposure. Options might include long-term contracts, feed-in tariffs (FITs) or contracts for difference (CFDs). Clearly, such measures should be available for nuclear power as well as for other low-carbon technologies, the great majority of which face similar issues. At stake is the ability to find convincing answers to the questions posed by the intrinsic capital-intensity of low-carbon technologies. OECD governments and the regulators within these countries have been slow to systematically react to the strategic divergence between electricity market liberalisation and investment in low-carbon electricity generation technologies such as nuclear energy.

The results unequivocally demonstrate that the competitive position of two technologies is affected by the level of price risk and consequently by the choice of market design. There is no technology-neutral market design. Due to the risk of a decline in the price level, a liberalised electricity market will generate results that are different from those of a regulated market in terms of the relative competitiveness of nuclear power. The often invoked level playing field could potentially mean very different things to different technologies because not all technologies depend on the regulatory environment in the same manner. The profitability of a gas plant varies far less in relation to the regulatory regime than the profitability of a nuclear plant.

This report is complemented by the results of a financial Monte Carlo model with symmetric electricity price risk, which also includes the financial risks pertaining to the costs of construction operations. Under the assumptions of the model, construction cost and electricity price risk are of comparable orders of magnitude and dominate the overall risk of an NNB project. Added to this is the differentiated risk exposure of bond and equity holders. Given the cost structure of nuclear power, risks are in effect relatively low for bondholders, since the low variable costs of NPPs would mean that production would rarely cease completely, even in the case of substantial price declines. Indeed, nuclear power is usually the last remaining dispatchable technology in the market. For debt ratios of up to 50% and permanent price declines of up to 40%, bondholders will be fully repaid as long as the cost of debt does not exceed 5.5% in real terms.

Financial risks are, on the other hand, comparatively high for holders of residual risk (i.e. equity holders), since, in the case of a price decline, they are unlikely to ever fully recoup their outlays, which has obvious implications when targeting government support for nuclear finance. The latter is traditionally geared towards bondholders, for instance in the form of loan guarantees. Due to the cost structure of NPPs, however, it is equity holders rather than bondholders that are the constituency most in need of support, as any change in electricity prices will mainly fall on equity holders. In the current long-term policy environment, this means primarily a downside risk. From this point of view, electricity price stability remains a decisive element for new nuclear projects.

Three case studies of NNB projects are included in the second part of the report, at Akkuyu (Turkey), Barakah (United Arab Emirates – UAE) and Vogtle (United States), as well as a presentation of the Finnish Mankala financing model. All four projects point towards arrangements for providing at least some degree of long-term electricity price stability. The latter include power purchase agreements (PPAs) with guaranteed prices, equity provided directly by the host country government, regulated tariffs or long-term contracts with commitments to take off electricity at average costs.

Managing complexity in a changing environment

Managing the complexities of constructing new NPPs, as well as of leveraging the potential benefits of an increasingly international supply chain is the focus of the third part of the report. This latter part of the report describes the current situation of the global nuclear industry, which is experiencing significant and discontinuous technological change as generation II NPPs are substituted by larger and more complex generation III/III+ plants. Two further elements are taken into consideration here. First, the loss of skills and human capital as a generation of engineers of the nuclear building boom of the 1970s and 1980s retire should be factored into the current situation. Second, the reconfiguration of the global supply chain of contractors and subcontractors, which is driven both by new possibilities in data management, externalisation and logistics, and by a fundamental shift of activity from the United States, Europe, Japan and Korea to China, Southeast Asia and the Middle East, should also be taken into account. While the latter constitutes a shift from OECD to non-OECD countries, many if not most major suppliers continue to have their headquarters in the OECD area.

The nuclear industry has undergone a major wave of consolidation among the main reactor vendors in the past two decades, a trend that may continue in the future. However, integration at the horizontal level does not preclude increased differentiation and co-operation with specialist suppliers along a vertical axis. A large section of the present report examines the evolving structure of the global nuclear supply chain and provides a detailed overview of the global nuclear industry, which combines consolidation at the horizontal level with the development of more differentiated profiles across the vertical value chain.

The key to efficient project management is finding the right balance between vertical integration and competitive procurement. The former is, of course, the traditional model for integrated vendors close to national authorities that in some cases are even able to include long-term fuel supply, maintenance and the removal of radioactive waste in their offer. This model has advantages that are recognised both in theory and in practice, such as the smooth integration of all parts and limited transaction costs through established command and control structures. Among the disadvantages, however, are inflexibility and the exercise of monopoly power.

Competitive procurement under an architect-assembler or a turnkey approach with an engineering, procurement and construction (EPC) contractor model is an alternative that holds promise but has yet to provide a sufficient number of convincing success stories. There is also some evidence that the hands-off, risk-off approach of working through EPC contractors is increasing overall costs as contractors, as well as several layers of subcontractors, hedge their respective financial exposure. This "pancaking" of financial margin on financial margin is partly responsible for continuing cost increases during the past decade.

When deciding on which financial and managerial model to choose, previous experience with NNB clearly matters. Less experienced customers will often go with relatively high-price, turnkey contracts, while customers with more experience go with multi-package approaches. However, experience also shows that NNB contains an element of residual, non-diversifiable risk related to technical, organisational and regulatory complexity. Not all risk can be diversified in a large construction project highly dependent on regulatory decisions. This brings new meaning to the seemingly old-fashioned notion of leadership, since at one point or another, someone needs to assume the residual risk and take responsibility for it.

Another major issue for the structure and efficiency of the global nuclear supply chain is the convergence and standardisation of industrial codes and quality standards. There are currently a number of private or public initiatives, such as the Nuclear Quality Standard Association (NQSA) in Europe, the Nuclear Procurement Issues Committee (NUPIC), which created the NSQ-100 standard, or the initiative on Co-operation in Reactor

Design Evaluation and Licensing (CORDEL) of the World Nuclear Association (WNA). Despite these initiatives, unification remains elusive, with the two big groups of codes, RCC-M/E and the American Society of Mechanical Engineers (ASME), continuing to exist in parallel. This co-existence impedes the emergence of a competitive global nuclear industry as it limits the scope of externalisation and co-operation between different companies. It also hinders benchmarking and an easy transferability of best practices across suppliers, which would constitute important stepping stones in the reduction of construction costs.

Regardless of the lack of global harmonisation in engineering and safety codes, the nuclear industry has nevertheless been adopting a number of technological and managerial improvements. Traceability of all components, 3D modelling or automatic welding are part of a number of incremental improvements that are nudging the industry towards higher levels of efficiency. On the management side, early involvement and training of suppliers, attention to the management of culturally diverse teams and explicit change management to prepare for unforeseeable mishaps are now part of the industry standard. Design completion before the start of production is also an important component of successful projects.

Nonetheless, it is safe to say that the global nuclear industry has not yet settled on a new equilibrium model and that different approaches that combine elements of the two reference models, the turnkey or architect-assembler model, are still being tested. The industry is clearly exploring different paths and has to some extent adopted a "wait-and-see" approach to determine if a new scalable business model will emerge from the surge in reactor constructions in Asia.

A dedicated section of the report examines the divergence between actual and estimated costs in large industrial and infrastructure projects. It asks whether "nuclear is special" and whether large cost and construction time overruns are confined to the nuclear industry, and concludes that this is not the case. "Megaprojects" in all industries are subject to similar challenges, although the past record of the nuclear industry remains slightly below that of its peers in other sectors of the energy industry in terms of building to time and budget, but this could well be a function of project size and complexity.

Design standardisation is of great importance. While there is some evidence for rising costs per MW of capacity over time across different reactor types, several studies provide encouraging evidence for cost savings as the number of completed reactors based on a particular design increases. Cases in point are France and Korea. In addition to the replication of a proven design, a key success factor is the existence of a stable regulatory and political environment with experienced stakeholders adopting a long-term view.

The third part of the report is rounded out by case studies of NNB projects at Shimane (Japan), Flamanville-Taishan-Hinkley Point (China, France, United Kingdom), Tianwan (China) and VC Summer (United States), pointing to change management and early supply chain planning, as well as "soft" features such as leadership, team building and trust, as key issues in the construction process.

Maintaining momentum

While different projects may have chosen different paths, these projects nonetheless share a number of features. On the financing side, financing capital-intensive NNB projects requires the long-term stabilisation of wholesale electricity prices, whether through tariffs, PPAs or CFDs. Empirical evidence also demonstrates that most nuclear new build projects occur in regulated markets or with the help of long-term contractual arrangements. Electricity market designs are not technologically neutral and if significant reductions in carbon emissions continue to be the objective of the electricity industry, a general rethink will be needed to determine how to finance capital-intensive, low-carbon generation technologies.

In construction, where the emergence of a competitive, global supply chain is not yet ensured, the convergence of nuclear engineering codes and quality standards remains a key step in promoting both competition and public confidence. In parallel, a number of smaller technological and managerial improvements keep the industry moving forward.

During a time of major technological, structural and geographical shifts, it is important that the global nuclear industry maintains a dynamic of continuous technological, logistical and managerial improvement at the level of the construction site, while preserving financial and regulatory stability at the level of the overall project. While it may be too soon to tell, there are sufficient promising developments under way to justify expectations for a new business model so that financially and economically sustainable new nuclear build projects can continue to emerge in the coming years.

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Nuclear new build has been progressing steadily since the year 2000, with the construction of 94 new reactors initiated and 56 completed reactors connected to the grid. Among these new reactors are some of the first generation III/III+ reactors of their kind. Drawing on a combination of conceptual analysis, expert opinion and seven in-depth case studies, this report provides policy makers and stakeholders with an overview of the principal challenges facing nuclear new build today, as well as ways to address and overcome them.

It focuses on the most important challenges of building a new nuclear power plant, namely assembling the conditions necessary to successfully finance and manage highly complex construction processes and their supply chains. Different projects have chosen different paths, but they nonetheless share a number of features. Financing capital-intensive nuclear new build projects requires, for example, the long-term stabilisation of electricity prices whether through tariffs, power purchase agreements or contracts for difference. In construction, the global convergence of engineering codes and quality standards would also promote both competition and public confidence. In addition, change management, early supply chain planning and "soft issues" such as leadership, team building and trust have emerged over and again as key factors in the new build construction process. This report looks at ongoing trends in these areas and possible ways forward.

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