WNA Report

Structuring Nuclear Projects for Success

An Analytic Framework

World Nuclear Association

Contents

Executive Summary

Recent years have seen a transformation both in the actual economics of nuclear power and also in the widening recognition that it occupies an increasingly strong position in the energy marketplace. A growing community of investors now understands that existing nuclear power plants are highly economic. Power prices have risen sharply with the escalation of oil and gas prices, while well-run nuclear plants have stable and predictable operating costs that ensure excellent profitability for their owners in any type of electricity market.

The economics of new nuclear plants are more challenging and are documented in a number of publications, including the WNA Report entitled "The New Economics of Nuclear Power" issued in late 2005. It has however become clear that, even with the most cautious assumptions on costs of plants, the price of natural gas and other relevant variables, new nuclear plants can now be economically viable. This prospect is strengthened by the likelihood that public policies will focus increasingly on penalizing energy technologies that produce carbon emissions.

Economic viability, however, is only one aspect that investors must consider when contemplating new nuclear projects. They have somewhat unique characteristics. They are capital intensive, with very long project schedules and have significant fixed operating and maintenance costs but relatively low fuel costs. They exist in a rigorous regulatory environment where the regulator very actively patrols the plant's operations and has considerable authority that can impact on both unit construction and operations.

Many utilities are extremely risk averse, some of them having suffered through projects that did not meet expectations in the past. Given the long period of time without any substantive new build projects, they are looking for ways to boost confidence that plants will be built to budget and schedule, so that the promise of good economic performance will be realized. This report describes the key risks facing those who are looking to build new nuclear plants and then demonstrates that a good structure is essential for project success.

The criteria for a successful project are all associated with managing and mitigating project risk. These include:

- Well designed economic plants
- Stable regulatory regime
- Risk sharing amongst all project stakeholders
- Strong project management

To properly structure a nuclear new build project for success requires a good understanding of the various risks associated with a project of this complexity and magnitude, then finding a contractual structure that allocates those risks amongst key stakeholders. Some are not so different to those pertaining to any power investment project, but others are clearly unique to nuclear. Although the list of risks is substantial - including regulatory, project delivery, operational and the electricity market - they can be mitigated through good management and planning. The remaining risks must be allocated to the appropriate stakeholder in the best position to take on that risk. In some cases, the risks can be allocated to the private sector, in others only government can take them on, while there are some risks that can be covered by insurance and other means.

The successful financing of nuclear construction depends on the project structure which is developed. This, in turn, must be determined on the basis of the relevant electricity market. With the right project structure - one that shares risks equitably among stakeholders and encourages each project participant to fulfil its responsibilities - nuclear power will succeed and investors earn substantial and reliable profits. In risk mitigation, government also has a very significant role. Nuclear projects cannot proceed without government support - in establishing and maintaining a sound framework for industry operation.

The nuclear renaissance has entered a chapter in which the maturity of the technology, its strong economic competitiveness and its inherent environmental advantages can and must be translated into soundly structured, highly profitable projects that yield nuclear new-build on a worldwide scale.

1 Introduction

There has been a surge of interest in nuclear power around the world as countries begin to recognise the benefits of low carbon electricity, improved security of supply and stability of generating costs. In many countries energy policy is directed by the government, but it is utility companies that make the decisions on which new power stations to develop and build. Nuclear power must therefore be competitive with other technologies. With nuclear energy's higher capital cost and longer development and construction period, utilities will focus on how risks can be managed and risk allocations optimized. The business case for nuclear will depend on this structure.

Although new nuclear power plants require large capital investment, they are hardly unique by the standards of the overall energy industry, where oil platforms and LNG liquefaction facilities cost many billions of dollars. Projects of similar magnitude can be found in the building of new roads, bridges and other elements of infrastructure. Many of the risk-control and project management techniques developed for these projects are equally applicable to building nuclear power stations.

Risks that are specific to nuclear plants are those surrounding the management of radioactive waste and used fuel and the liability for significant nuclear accidents. As with many other industrial risks, public authorities must be involved in setting the regulatory framework. The combined goal must be public safety and the stable policy environment necessary for investment.

To support new-build projects, they must be structured to share risks amongst key stakeholders in a way that is both equitable and that encourages each project participant to fulfil its responsibilities. This paper identifies key risks associated with a nuclear power project and how they may be managed to support a business case for nuclear investment.

2 Risks of nuclear projects and their control

Structuring a nuclear new-build project for success requires the identification and understanding of the various risks associated with a project of such magnitude and complexity. Some risks are quite similar to those in any power investment project; others are clearly unique to nuclear. In developing a project, a utility will undertake a comprehensive risk assessment, which will be reviewed and updated as the project progresses.

Nuclear projects are capital intensive, with long project schedules. They have significant fixed operating and maintenance costs and relatively low fuel costs. They exist in a rigorous regulatory environment where the regulator actively patrols plant operations and has considerable authority to impact unit construction and operations. Nuclear plants are also subject to public scrutiny and concern. In normal operation, nuclear plants are environmentally friendly. At the same time, public concerns often focus on the questions of long-term management of nuclear waste and potential consequences of low-probability safety events.

Table 1 lists risks that are associated with a nuclear project. Table 2, in section 3, shows how these may be mitigated.

Table 1: Nuclear power project risk matrix

	Development	Construction	Operation	Decommissioning
Technical	Regulatory assessment Site suitability Environmental impact Planning approvals	Safety Design completion/changes Regulatory assessment/approvals Vendor & Contractor performance Equipment supply chain Skilled & experienced workforce Construction quality Transport routes to site Industrial relations Plant performance	Safety Plant performance Skilled & experienced workforce Nuclear event elsewhere Nuclear event The environment Fuel supply chain	Safety Design completion/changes Regulatory assessment/approvals Contractor performance Equipment supply chain Skilled & experienced workforce Transport routes to/from site
Business Case	Economics Demand forecast Used fuel & radioactive waste disposal	Design changes Delay	Electricity trading arrangements Electricity price Carbon price Fuel costs Capital additions Early closure Cost of waste and used fuel disposal Decommissioning fund performance	Decommissioning fund
Societal & Political	General public support and local approval Policy supporting the need for nuclear power Policy for waste management Decommissioning & waste management mechanism Carbon pricing mechanism Environmental policy			

Construction schedules for nuclear projects are notably long. This can influence the allocation of cost-inflation risk in relevant construction contracts. It can also impact on the negotiation of power purchase agreements (PPAs), if these are a requirement before construction commences.

In preparing its risk assessment a utility may assess the probability of the event occurring and the consequent impact. Measures to manage or monitor the risk can be identified and a further assessment made of the residual probability and impact These methods are not unique to nuclear power projects and are discussed below.

2.1 REGULATORY

Safety is of utmost importance in nuclear operations. Regulatory power is significant and concerns can delay or halt nuclear plant construction or operations. While public protection is an essential governmental responsibility, that goal must be pursued, to the maximum extent possible, through a regulatory environment that provides sufficient predictability to elicit the investment necessary to bring the benefits of nuclear technology to the public. The nuclear industry has come to recognize that it can contribute to stability and smoothness in the regulatory process by achieving greater constancy in reactor designs. Ultimately, the public interest is served by regulatory certainty combined with smooth procedures.

The regulatory licensing process can be broken into several stages. The first is reactor design certification. The second is site approval (made easier in locations with previously constructed reactors). Next come licenses for construction and operation. Additionally, in most countries local planning approvals are needed both by law and as a means of achieving and demonstrating public acceptance.

Recent U.S. experience provides a good example of a step forward in strengthening regulatory certainty in the new-build process. The Nuclear Regulatory Commission (NRC) has established a licensing framework that provides for pre-approval of a prospective site for a new plant, certification of reactor designs well ahead of any construction and the issuance of a single license to build and operate a new plant using a certified design and a pre-approved site - a combined construction and operating license called a COL.

The new approach moves all design, technical, regulatory and licensing issues to the front of the licensing process. Before construction begins and any significant capital spending occurs, safety and environmental issues can be fully addressed. The new licensing framework aims to assure potential investors that their investment in a new nuclear plant will not be jeopardized as long as construction adheres to the approved design and standards. Delays caused by public intervention in the past are now prevented by strictly defined time-frames for public hearings and consultations. It bears emphasis, of course, that adequate staffing of regulatory agencies is important for timely decisions.

2.2 PROJECT DELIVERY

New-build risks include costly delays due to problems with designs, equipment supply, project management, construction and commissioning. These risks, not unique to nuclear, can be allocated amongst the plant owner-operator, the plant engineering, procurement and construction (EPC) contractor, the plant vendor and financiers. Contracts can provide for a fixed delivery price, with penalties for delays and incentives for completion ahead of schedule or below budget.

A new generation of reactors has been designed to reduce project risks. Building these reactors using pre-fabrication, pre-assembly and modularisation along with 3-D modelling, open-top construction and other advanced construction techniques can further control risks. The new reactor designs take advantage of the significant R&D, construction and operating experience available in what can now be called a mature technology. The design advances include a variety of safety features.

The nuclear industry (the large reactor vendors and utilities) is now working in cooperation with national and international regulatory and safety bodies with the aim of harmonizing regulatory and utility requirements to reactor designs throughout the world. Such harmonization would lower costs for manufacturing, construction, maintenance and refuelling outages. Standardized designs can be produced en masse and with economies of scale.

It has been recognized that those who build the first reactors of a new design (first of a kind, or FOAK) bear the burden of one-time risks and provide followers with valuable information and experience. To reward this benefit, the US government has introduced FOAK incentives that include loan guarantees, investment tax credits and insurance against regulatory delays. These may be deemed appropriate in other markets.

Countries that are introducing nuclear power for the first time are already subject to considerable start-up burdens. They are therefore well-advised to adopt proven designs that have already passed the FOAK stage.

Because nuclear projects are especially capital-intensive, effective project management is essential if risks are to be managed, costs contained and schedules met. In this fundamental respect, nuclear new-build projects are little different from any other major construction project; they demand top management personnel applying proven techniques.

2.3 OPERATIONS

While nuclear operations clearly involve a variety of risks, it should be noted that existing nuclear plants are now being run very professionally in some thirty countries around the world - creating a strong foundation for the operation of new reactors in those nations as well as other countries now preparing to initiate nuclear power programmes. Nuclear operations have benefited from skill improvement programs, the advice of nuclear regulators and the sharing of information and technical assistance through international professional associations (notably, the World Association of Nuclear Operators). Enhanced maintenance and support services now guarantee performance for up to 60 years, so future operational risks are likely to be deemed less significant than in the past.

Clearly the risk of poor operational performance can be controlled by the employment of well-trained and experienced workforce, applying a carefully planned and implemented maintenance regime. Ongoing support from vendors is also important in controlling any technological risk associated with new designs.

With regard to the replacement of plant equipment, the business case for new-build may require that the project include a contingency fund for some capital expenditure through the life of the plant, in addition to predicted replacements identified in the vendor's design. With regard to fuel, the utility must also consider its fuel procurement strategy to control any cost or supply-chain risks.

On nuclear liability, plant owners carry insurance to cover most operating risks. Liability for severe accidents is defined by international conventions (notably, the Vienna and Paris conventions) and/or by national legislation (such as Price Anderson in the United States). In contrast to many other industrial sectors, these frameworks have the advantage of precisely defining the liability borne by the operators, with public authorities covering the interests of residual claimants.

Finally, plant security concerns from natural events (e.g., earthquakes or severe climatic conditions) are covered in new plant evaluations. Protection against terrorist attacks clearly requires collaboration and support from government authorities.

2.4 DECOMMISSIONING

End of life risks relate to the radioactive waste and used fuel management and plant decommissioning. Used fuel is regarded as part of the fuel cost, with an annual charge levied to take account of management. It depends, however, on an appropriate national political framework being established.

Decommissioning costs are covered by annual charges levied to cover the ultimate cost, fixed by national rules, similar to used fuel. Alternatively, a sum can be added to the capital cost of the plant and guarantees can be granted by the owners to the government for any uncovered sum from plant start up.

2.5 ELECTRICITY GENERATION

A fundamental aspect of any new-build project is that the plant will achieve a ready market for its electricity at favourable prices. This evaluation must include future levels of grid power demand (or availability of potential customers for electricity), future market status of competing energy sources and the long-term prospect for emission-trading mechanisms and other penalties on carbon.

The plain economics of electricity generation, whether from base-load or peak-load plants, requires electricity prices at a level sufficient to cover the full costs of capital and operations. Spot and short-term prices that reflect business cycles must be complemented by guaranteed long-term prices both on the wholesale and retail markets. Peak-load and semi-base-load plants are the most exposed to market risks, but base-load plants such as nuclear must also achieve some market assurance. A sole nuclear generator with no retail customers is particularly vulnerable to the risk of low prices. Measures to control this risk could include long term power off-take arrangements or managing a nuclear plant within a vertically integrated utility that has a diversified portfolio of generating sources and its own customer base.

Fuel price risks must be taken into account. For example, gas-fired plants have faced major problems as gas prices have escalated. In liberalised power markets, where coal or gas is the predominant fuel, the electricity price is likely to be correlated with the marginal costs of these plants. The volatility of the prices of these fuels can then partly be transferred to electricity prices, which bear no correlation with costs of nuclear generation. This is a risk for volatility in earnings for a nuclear plant that utilities may seek to control through the measures highlighted above. It is important to note that all base-load generation modes require major capital investments and some security in power off-take, so they can encounter difficulties in the merchant plant model. In the significant bankruptcies of merchant plants that occurred in the USA in 2001-2002, not surprisingly most of the plants affected were those fuelled by natural gas.

The degree of market risk depends crucially on the market structure. It is certainly no coincidence that many of the early new nuclear plants proposed in the USA are located in areas where electricity markets are still regulated, so that plant investment costs can be recaptured with greater assurance.

International and national emission-reduction policy frameworks should benefit nuclear investments and reduce market risks. In countries with a significant proportion of fossil fuels in the energy mix, an increased penalty on carbon will entail rises in the marginal cost of fossil generation. By raising wholesale electricity prices, carbon penalties will increase the rate of return on nuclear investment. Still, because of the relative novelty of emission-reduction policies, nuclear investors will need to gain confidence in the government commitment to carbon pricing or any other mechanism designed to reward long-term investment in low-carbon technologies.

2.6 POLITICAL

Governmental commitment to the need for nuclear power is a pre-requisite to any nuclear construction, but that commitment cannot obviate all risks of changing laws and regulations governing electricity markets and taxation.

Another political risk is that the tide of public acceptance could turn, undermining a project's viability during or after construction. Barring unforeseen and extreme events, however, utilities are in a strong position to minimize this risk by drawing upon the industry's considerable experience in dealing with questions of public concern. In most countries, the industry has succeeded in gradually building public support for nuclear power, by demonstrating strong operating performance. The industry's excellent safety record is the basis on which policymakers have been able to point to nuclear energy as an important response to the imperatives of energy security and environmental protection.

3 Project structure and risk allocation

The essential aim of project structuring is to achieve the most efficient application of capital and resources. Project risks must be assigned to the party most capable of handing their control.

The structure of a new nuclear power project will be also be influenced by the market in each particular country or region. A project in a liberalised market will no doubt be structured differently to one in a regulated market. In a regulated market, investments may be made following regulatory scrutiny of a plan which, once agreed, allows all costs to be passed through to the consumer. This structure still depends on the quality of the regulator and its control processes.

There is no "right way" to structure a nuclear project. A number of project models can succeed. The essential characteristic is a suitable sharing of risks and benefits.

Although project structures may vary, and can be complex in some markets, there will still be similar parties involved and the allocation of risks will always be a key factor in assessing whether the business case for a nuclear power station can be assembled. Simply transferring a risk does not make it disappear. The receiving party must demonstrate that it can control the risk if uncertainty is to be lowered to acceptable levels.

The prime participants in a nuclear project are:

- **Government** - which is responsible for overall energy policy and, in some cases, financing
- **Market** - formed by electricity customers wanting electricity at a competitive price
- **Utility (generator)** - which is ultimately responsible for developing the complete project
- **EPC contractors** - engineering, procurement and construction companies which are responsible to the owner for delivery according to schedule and budget
- **Vendors** - which are responsible for supplying equipment and technology to either the owner, the EPC contractor or as part of a joint venture or consortium, according to schedule and budget
- **Safety authority** - which is responsible for addressing all matters related to protecting public safety and the environment, from the design stage to plant operation and fuel management.

Table 2 shows ways in which the risks of nuclear projects can be monitored and controlled, to match Table 1.

Table 2: Risk control and monitoring in nuclear power projects

	Development	Construction	Operation	Decommissioning
Technical	Internationally-accepted designs Building on existing nuclear sites	Develop sound contractual arrangements for involved parties Invest in supply chain infrastructure Good training programmes Invest in transport infrastructure near the site Previous construction experience Strong project management	Involvement in WANO, INPO etc Good training programmes Invest in new nuclear fuel facilities "Fleet" approach to reactor management Invest continuously in plant maintenance and improvement	Decide on decommissioning strategy as early as possible Invest in workforce training
Business Case	Seek investment from major power users Build business case on various demand scenarios	Stick to standardized designs Use good mix of permanent and contract staff	Develop sound long term power contracts Develop good balance of fuel contracts Nuclear knowledge management	Contribute to well-defined fund as required
Societal & Political	Public debates and hearings Regular opinion polling Gaining cross party political support Emphasize environmental advantages of nuclear Develop WM policy with government			

3.1 DEVELOPMENT

During the phase of project development when government effectively controls the permitting and approvals process, the risk of the design being rejected or the project delayed is likely to be carried by the utility and potential reactor vendors. Using internationally-accepted designs, preferably already built elsewhere, can help to control risks of rejection or delay, but substantial sums of money can be committed, and at risk, even before the first concrete is poured.

3.2 STAKEHOLDER INVOLVEMENT

Stakeholder participation is a key to allaying legitimate concerns about waste management and the safety and security of nuclear installations. Public hearings and debate are sound means for improving dialogue and ultimately saving time. Providing information to the public and their representatives is essential to building social trust. Such information also serves a documentary function, placing in the open record what has been proposed and approved, to avoid the possibility of recurrent argument.

3.3 CONSTRUCTION

During the construction phase, the various risks can be covered by contractual arrangements among the utility, EPC contractor and vendors. Here there is a range of possibilities. For example, in a turnkey project the EPC contractor can assume almost all risks of cost overruns. Financial penalties and rewards are common, for parts of the construction contract relating to timing and quality. As an alternative, utilities can assume greater risk in exchange, perhaps, for the opportunity to benefit from a lower overall cost. EPC contractors and vendors will limit their exposure and ultimately a portion of the risk will still reside with the utility. Because nuclear plants are very expensive, risking company balance sheets, forming consortia to share risks may often be a good solution.

3.4 OPERATION

Once a plant is running, the utility will control most of the risks - specifically, for safe operation, for achieving high capacity factors and for maintaining control of O&M costs. In controlling fuel and O&M costs, the utility can use long-term deals with suppliers and contract out key services such as plant outages.

During operations, there are obvious benefits to using reactors of standardised design and of running a series of reactors in a "fleet" approach. Sharing the fixed costs and a common supply chain - and taking advantage of knowledge and experience at similar plants - plainly enhances both economic and safety performance.

Operators can gain performance benefit and also security from regulatory penalty by responding actively and cooperatively to advice from regulatory and safety authorities. Such responsiveness, coupled to transparency in plants operations, contributes to public trust and acceptance. For example, in the areas surrounding French nuclear plants, local information commissions meet regularly, bringing together utility officials from EDF and stakeholder representatives.

3.5 DECOMMISSIONING

Plant decommissioning, as well as the management of waste and used fuel, must be the responsibility of industry players, operating within a sound regulatory framework. Public authorities must, however, bear policy responsibility for ensuring the establishment of facilities for the management, storage and disposal of long-life wastes.

4 The role of government

Nuclear power requires governmental support in the form of policies that affirm its value and establish a framework for its operations. Inevitably, issues surrounding radiation and possible weapons proliferation create public interest, and governments must respond. How effectively government responds in satisfying public concerns affects the political and public context - the degree of uncertainty - surrounding nuclear projects. Where nuclear issues remain controversial, uncertainty carries a significant premium in the business case for new nuclear power stations.

As a starting point, government must have a commitment to nuclear power as a part of national energy strategy. This must include a considerable degree of cross-party consensus. Clearly there cannot be cast-iron guarantees that government policy will not change, but there needs to be at least an agreement that the need for nuclear power is recognised as a long-term commitment. This essential requirement is not unique to nuclear energy

A government supporting nuclear power can reasonably be expected to undertake the following:

- **Energy policy** - As a reference point and guide for all stakeholders, government must define a sound long-term energy policy addressing the major challenges of energy efficiency, security of supply and environmental protection.

- **Regulatory and local planning system** - Government oversight authorities must apply standards in such a way as to meet the twin objectives of protecting public safety while facilitating the gain from the production of clean and reliable nuclear power. This should ideally be made as smooth, consistent and risk-informed as possible To enhance efficiency and lower costs, construction and operating licenses should best be issued together. The local planning process should concentrate on local issues, ensuring full deliberation within a time-limited framework.

- **Safety regulation of operations** - This is the prime responsibility of national government, but responsibilities are increasingly being discharged with reference to internationally accepted standards and norms.

- **Radioactive waste and used fuel management** - Government must accept and act on its responsibility to develop and implement a national policy on the long-term storage of radioactive waste and used fuel, while coming to terms with the issues of reprocessing and geological repositories. While plant operators should expect to contribute a full share of costs, governments must lead on this sensitive but fundamental issue.

- **Decommissioning** - Government policy must ensure that each plant operator makes financial provision for decommissioning, using a fully segregated fund.

- **Nuclear liability** - Government must have a clear and consistent policy and legal framework defining the respective insurance responsibilities of government and nuclear operators.

- **Power market** - Government must conduct an affirmative policy designed to facilitate and ensure an efficient and reliable energy market that provides some excess of capacity to meet growth and unexpected demand. To achieve this, the market regime must be designed to encourage long-term investment.

- **Climate change** - Any government pursuing a serious policy on the mitigation of greenhouse gases (GHGs) must support measures to penalize carbon emissions.. A policy that penalizes carbon inherently strengthens the competitive position of nuclear power. An example of institutionalized carbon penalties is the European emissions trading scheme (EU-ETS), a regional system of GHG pricing. Similar systems are being developed in Australia and the USA. An alternative is direct carbon taxes. Internationally, within the UN Framework Convention on Climate Change (UNFCCC), governments now aim to design, during 2009, a post-2012 GHG reduction system. This design should treat nuclear, without discrimination, as an important low-carbon technology

5 Financing

All discussion of nuclear financing must inevitably focus on one essential principle: A good project structure will attract financing at the lowest possible cost. Contrary to common belief, there is no magic formula which financiers can suddenly produce to allow difficult projects to proceed.

The two elements of financing are equity and debt. Equity holders - investors willing to take risk in exchange for adequate return - have a differential tolerance for risk. With more complex project structures, investors will perceive more risk, increasing what they will require in expected return.

In assessing whether they will provide debt financing, banks and other lending institutions will evaluate a project's creditworthiness. In the case of project finance, they will look for a strong set of creditworthy contracts. More often, the borrower will be a single organization such as a large utility; here the lender will look for a strong balance sheet and will also weigh the borrower's experience in building and operating a fleet of nuclear and other units. Lenders do not take risk other than the credit risk of a borrower and require certainty that their loan will be repaid on a given date.

Many investors, notably in the US, lost money on nuclear and coal plant investments when market liberalization ended the ability to pass on all costs to customers and left a legacy of "stranded costs" (i.e., those unlikely ever to be repaid by subsequent operating profits). Then, in the late 1990's and early 2000's, electricity trading arrangements in many markets changed fundamentally, leaving some financiers cautious about the entire energy sector.

Within complex structures, financial institutions can be innovative and creative but there are limitations on what they can achieve. Nonetheless, today they do not appear reluctant to invest in nuclear. There is indeed, it is said, a huge wall of money seeking profitable investments. For nuclear projects to gain financing requires only that projects be structured so as to demonstrate clearly that they are creditworthy.

5.1 ELECTRICITY MARKETS AND FINANCING

The structuring of the nuclear project - and how it is financed, particularly the relative amounts of debt and equity - depend heavily on the model of plant ownership and nature of the power market. Both are crucial in how risks are handled.

There is now a wide variety of electricity markets, representing many important national differences. In general, they fall under four headings:

- **Regulated utility** - This is the "traditional" model for the power market. Here generating plants operate under cost-of-service rate regulation and have market outlets for the electricity within the same company. This model gives potential investors more comfort as costs can usually - subject to scrutiny by regulators - be passed onto customers. Lenders are secured by access to the assets and revenues of generating companies as well as by a strong degree of market assurance.

- **Unregulated merchant generating plant** - This is the "new" model of the power market. Here generating plants compete and have no direct outlets for selling electricity. This liberalized market entails a significantly greater exposure to price risk, which must be mitigated by long term power purchase agreements (PPAs) or support from a parent company. Projects in these higher-risk markets will require a less leveraged balance sheet - more equity and less debt - and also greater security for debt.

- **Hybrid** - World experience with electricity market liberalisation has generally tended to produce the kind of evolution that has occurred in Europe. There power markets consist of some merchant generating plants but evolve towards a small number of vertically integrated large utility groups, with a spread of generation facilities and regional supply outlets. Such large groups use their large balance sheets to invest in generation projects with some security on the selling side.

- **Investment** in nuclear is now attractive to utilities previously not involved in the sector. These are likely to participate via long term partnership agreements for building and operating nuclear plants, typically with other companies more experienced in the business..

The early stages of a nuclear project will generally require substantial equity investment, probably from major power companies or at least financing via their own balance sheets. This requirement, particularly if a fleet of nuclear plants is planned, will often invite the creation of a consortium of companies. As a project proceeds and risk points are passed and first revenues come closer, debt financing will usually become easier, and refinancing of earlier loans can occur.

Specific financing routes for nuclear projects include:

- **Balance sheet financing by utilities** - Many utilities, especially in Europe, are integrated electricity service providers with strong balance sheets that enable them to finance even large capital costs, such as nuclear power plants.

- **Project finance** - Debt investors lend to a single-purpose entity, whose only asset is the new power plant and whose only revenue is future power sales. This has advantages for sponsors as projects are highly leveraged. They need to contribute much equity only at a later stage, while their other assets are protected. The difficulty is attracting debt financing at reasonable rates, but a government loan guarantee (as is proposed for initial new plants in the United States) could change this.

- **Public-private partnership** - These have been adopted for many infrastructure projects, especially in the United Kingdom. At one extreme this could see a government-run competition for a company (or more likely a consortium) to build, finance and operate a specified number of nuclear plants. Locations and technology could be specified, and some guarantees given on FOAK costs.

- **Power user investment** - In this model, which was adopted for the 5th Finnish reactor, the equity has largely been contributed by a consortium of local energy-intensive industries and local utilities. They will take the output of the plant at cost, amortizing the debt portion from the market. If the plant operates well, owners will receive relatively cheap electricity over a long period, avoiding the risks of having to buy or sell power on the open market at uncertain prices.

5.2 COST OF CAPITAL

The capital intensity of nuclear projects means that the cost of capital strongly influences total generation cost and competitiveness against alternative technologies. Despite an increased ability to mitigate many risks, the historical experience of delays in plant construction in some countries has resulted in the perceived need for a substantial risk premium on lending for new nuclear investment - between 3% and 5%, as compared to other technologies. Nuclear projects may also require a higher initial equity share, adding to the cost of capital. These differences can be crippling to project economics. Risk perception initiates a vicious circle, whereby adverse risk perception leads to more costly financing, which makes the project look even riskier in financial terms. This syndrome must slowly be overcome.

The cost of capital is variable, with merchant generating plants attracting a higher risk premium, which inhibits large nuclear projects. In contrast, large, well-established and vertically integrated electricity companies with strong balance sheets have ready access to relatively cheap borrowing on a large scale and can also withstand a high gearing (debt to equity) ratio. They are more likely to be the best model for new nuclear power projects.

Alternatively, where large power customers invest in the nuclear plant and agree to take the output under long term arrangements (as in the case of the 5th Finnish reactor, where there is no risk premium) or in the US regulated market, the cost of capital should be relatively low as many risks are mitigated.

Clearly, reducing the risk perception - and the consequent risk premium - is essential to future nuclear projects. This gain can be expected to occur over time as early projects, such as those being developed in the USA, demonstrate a clear break with the past and make clear that risks can be mitigated by sound project structures. These initial successes should also induce greater public confidence, support and acceptance, leading to a virtuous circle of declining risk perception for future projects.

In a context of high-priced and volatile electricity markets, certain inherent features of nuclear energy should contribute to this lowering of risk perception, as compared to alternative technologies. These include:

- Cost stability, resulting from the low share of fuel in overall operating costs
- Fuel supply security
- High capacity factors, resulting from professional management and low variable costs
- Absence of any need for long-term subsidy (leaving aside the desirability of certain pump-priming measures to accelerate the nuclear renaissance)
- Absence of risk of carbon emissions costs

6 Conclusion

Nuclear projects have unique characteristics. They are capital intensive, with very long project schedules, but - once operational - they have remarkably low fuel and other operating costs. Nuclear plants also exist in a rigorous regulatory environment and are subject to significant public scrutiny and concern. These characteristics affect the structuring of nuclear new-build projects.

Experience has shown that nuclear projects are structured for success when risks are allocated amongst key stakeholders in a way that is equitable and encourages each participant to fulfil its responsibilities.

Government policy that recognizes the value of nuclear energy must be accompanied by government action to create the conditions for private investment in new nuclear power plants. Several models for such investment are available, and once a sound project structure is created, the ultimate key to success is strong project management.

The World Nuclear Association is the international private-sector organization **supporting the people, technology, and enterprises** that comprise the global nuclear energy industry.

WNA members include the full range of enterprises involved in producing nuclear power – from uranium miners to equipment suppliers to generators of electricity.

With a secretariat headquartered in London, the **WNA serves as a global forum** for industry experts and as an authoritative information resource on nuclear energy worldwide.

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