Nuclear Technology Development and Economics
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# Effective Frameworks and Strategies for Financing Nuclear New Build

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

## ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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## NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 34 countries: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia (suspended), the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally sound and economical use of nuclear energy for peaceful purposes.
- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of NEA competence include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.



*Cover photos: Financing (lovelyday12/Sutterstock); Steam generator transportation to Hinkley Point C, United Kingdom (EDF).*

# Foreword

In December 2023, at the 28th Convention of the Parties (COP28) to the United Nations Framework Convention on Climate Change (UNFCCC), Parties concluded the first-ever *Global Stocktake* to assess where the world stands on climate action under the Paris Agreement. While nuclear energy had essentially been absent from UNFCCC COP discussions since the signature of the Kyoto Protocol in 1997, the COP28 *Global Stocktake* recognised that nuclear energy is part of the solutions to reach net zero by 2050 in order to limit global warming to 1.5°C.

At COP28, 25 countries further underlined the role of nuclear energy in their climate strategies by issuing a Declaration on Tripling Nuclear Energy by 2050. This Declaration built on the NEA analysis of the role of nuclear energy in pathways to net zero and recognised the importance of financing nuclear energy projects. The Declaration further included a clear commitment to mobilise investments in nuclear power, including through innovative financing mechanisms.

Undoubtably, financing, alongside supply chain readiness and workforce, is one of the most pressing challenges that countries around the world must address to succeed with plans for new nuclear energy projects. In OECD and NEA countries specifically, mobilising investments in nuclear energy is further complicated by the recent track record of nuclear new build projects that have faced significant costs overruns and delays. In parallel, the energy sectors in OECD and NEA countries have also experienced structural transformations since the last wave of nuclear new builds in the 1970s and 1980s, with a liberalisation of energy markets and some degree of restructuring and privatisation of power utilities. Those changes are significantly influencing how financing frameworks for nuclear new build can be effected, including understanding the roles of public and private stakeholders.

In this context, this report provides policymakers, financiers and other relevant stakeholders with a comprehensive review of the range of financing frameworks and strategies that have been implemented or are presently under consideration for nuclear new build projects around the world. The objective of the case studies presented in this report is to establish a common vocabulary and the basis for comparative analysis in order to identify and discuss key lessons learnt about the relative merits of different strategies to finance new nuclear projects.

While each financing framework is unique to the national and industrial contexts where the project is implemented, a key finding of this publication is that these financing frameworks share several common "building blocks", of particular interest to policymakers in countries that seek to expand the role of nuclear energy in their energy mixes. While there are no simple solutions for financing new nuclear projects, this report helps identify the "building blocks" that policymakers and private sector decision makers can leverage to help finance a tripling of nuclear energy by 2050.

William D. Magwood, IV
Director-General, Nuclear Energy Agency

# Acknowledgements

This report was led and written by Michel Berthélemy, Senior Strategic Advisor in the Division of Nuclear Technology Development and Economics (NTE) at the Nuclear Energy Agency (NEA). Diane Cameron, Head of the NTE Division, provided management oversight and detailed comments throughout the preparation of the report, particularly on methodology and comparative analysis. Jan Host Keppler, Senior Economic Advisor, NTE, provided valuable comments during the preparation of the report. Tristan Besserve and Yereen Kim, NTE interns, made significant contributions with research and drafting of the case studies.

The nuclear financing case studies presented in this report benefited from detailed feedback from key project stakeholders that significantly contributed to improving the quality of the overall publication.

Last, but not least, the report also benefited from the oversight and extensive comments of the NEA Committee on Nuclear Development and the Fuel Cycle (NDC) under its Chair Patrick Lederman and the NEA Working Party on Nuclear Energy Economics (WPNE) under its Chair William D'haeseleer and co-Chair Brent Dixon.

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# List of abbreviations and acronyms

| | |
|---|---|
| **CfD** | Contract for difference |
| **CGN** | China General Nuclear Power Group |
| **DOE** | Department of Energy (United States) |
| **EC** | European Commission |
| **EDF** | Électricité de France |
| **ENEC** | Emirates Nuclear Energy Corporation |
| **EPC** | Engineering Procurement Construction |
| **EPR** | European Pressurised Reactor |
| **EWEC** | Emirates Water and Electricity Corporation |
| **FANR** | Federal Authority for Nuclear Regulation (United Arab Emirates) |
| **FDP** | Funded Decommissioning Programme (United Kingdom) |
| **FFB** | Federal Financing Bank (United States) |
| **FOAK** | First-of-a-kind |
| **GSP** | Government support package |
| **HAEA** | Hungarian Atomic Energy Agency |
| **HPC** | Hinkley Point C (United Kingdom) |
| **IGA** | Intergovernmental agreement |
| **IPCC** | International Panel on Climate Change |
| **KEPCO** | Korea Electric Power Corporation |
| **KHNP** | Korea Hydro & Nuclear Power |
| **LCCC** | Low Carbon Contracts Company |
| **LCOE** | Levelised cost of electricity |
| **MEAG** | Municipal Electric Authority of Georgia |
| **NCCR** | Nuclear Construction Cost Recovery |
| **NEA** | Nuclear Energy Agency |
| **NNBG** | Nuclear New Build Generation Company |
| **NRC** | United States Nuclear Regulatory Commission |
| **O&M** | Operation and maintenance |
| **ONR** | Office of Nuclear Regulation (United Kingdom) |
| **OPC** | Oglethorpe Power Corporation |

| | |
|---|---|
| **PPA** | Power purchase agreement |
| **PSC** | Public Service Commission |
| **PTC** | Production tax credit |
| **RAB** | Regulated asset base |
| **SMR** | Small modular reactors |
| **SPV** | Special purpose vehicle |
| **SSIA** | Secretary of State Investor Agreement |
| **TVO** | Teollisuuden Voima Oy |
| **UAE** | United Arab Emirates |
| **UK** | United Kingdom |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **US** | United States |
| **WACC** | Weighted average cost of capital |

# Executive summary

## The net zero imperative and the role of nuclear energy

According to the International Panel on Climate Change (IPCC), achieving the objectives of the Paris Agreement will require greenhouse gas emissions to peak this decade before reaching net zero by 2050. However, the world is not on track and energy-related carbon emissions, which represent about three quarters of total carbon emissions worldwide, continued to grow in 2023 (IEA, 2024a). Under-investment in low-carbon clean energy technologies remains a key driver behind this trend in emissions, with more than one-third of energy-related investments flowing towards fossil fuels (IEA, 2024b).

Today, nuclear energy plays a significant role in climate change mitigation efforts. As of 2023, nuclear energy is the second source of low-carbon electricity in the world after hydropower. Over the past 50 years, the use of nuclear power has reduced $CO_2$ emissions by over 70 gigatonnes – about two years' worth of current energy-related emissions. Analysis by the NEA concludes nuclear energy can and is indeed due to play an even larger role. Climate mitigation pathways considered by the IPCC for limiting global warming to 1.5°C require on average nuclear energy to triple to 1 160 gigawatts of installed capacity by 2050, up from 394 gigawatts in 2020 (NEA, 2022).

## The challenge of nuclear financing in OECD and NEA countries

Scaling up investment in low-carbon energy technologies, such as new nuclear power plants, requires immediate action. NEA (2022) analysis highlights that a tripling of installed nuclear capacity by 2050 would require the rate of annual new builds to at least quadruple from about 7 GWe on average over the last decade to 25-30 GWe in the coming decades. Investment flows in the nuclear sector will need to increase by a similar order of magnitude to meet this target.

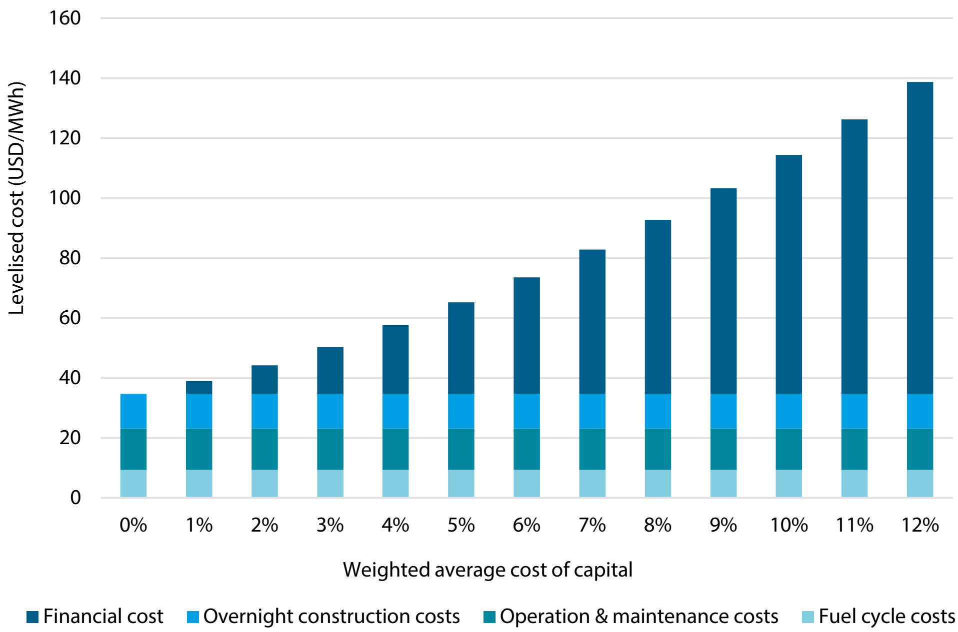
Today, scaling up investment flows in nuclear energy is one of the major challenges alongside supply readiness and workforce development for OECD and NEA countries that have decided or are considering the construction of nuclear power plants.

Financing conditions impact the levelised cost of electricity (LCOE) through the cost of capital, ultimately influencing the competitiveness of new nuclear power plants. As illustrated in Figure ES1 below, the LCOE for new nuclear power plants is particularly sensitive to the cost of capital owing to the importance of fixed investment costs relative to variable costs, and the long construction period. For instance, financial costs can represent two-thirds of the costs of nuclear electricity when the cost of capital reaches 9% but drop to less than one-third if the cost of capital is lowered to 3%.

It is useful to think of financing as a project output, rather than a project input. Financing conditions are primarily the outcome of decisions regarding the management of the different risks affecting the project. Today, most OECD and NEA countries are emerging from a long hiatus without the construction of new nuclear power plants. This has resulted in a loss of supply chain and workforce capabilities which, in turn, have contributed to significant delays and associated cost overruns for recent first-of-a-kind (FOAK) nuclear energy projects. Consequently, nuclear energy projects are associated with significant real and perceived construction risks, which directly impact financing conditions as most private investors require a higher return to accept a higher level of risk.

The energy sectors in OECD and NEA countries have experienced significant transformations since the 1970s and 1980s when most of the existing nuclear power plants were built and financed. In several countries, energy markets have been liberalised and power utilities have been restructured and/or privatised. Accordingly, financing frameworks for new nuclear power plants need to be adapted and similarly restructured.

Figure ES1: **Levelised costs of nuclear electricity for a range of cost of capital**




Source: NEA (2020).

## NEA nuclear financing case studies: Objective and methodology

This publication presents eight case studies, taking stock of the range of financing frameworks and strategies that have been recently implemented or are presently under consideration for nuclear new build projects around the world. The objective of these case studies is to establish a common vocabulary and the basis for comparative analysis to identify and discuss key lessons learnt about the relative merits of different strategies for financing nuclear projects.

These NEA nuclear financing case studies provide source of information about the drivers and features of recent nuclear financing models and present the characteristics of each case study in a system diagram format that facilitates understanding and analysis. The eight case studies presented in this publication are summarised in Figure ES2 and Table ES1 below.

To conduct these case studies, the NEA developed a methodology to compile, synthetise and analyse publicly available information. For each case study, this includes detailing the financing framework in a system diagram that captures the roles of the different stakeholders, the sources of equity and debt financing, the revenue streams, and the role of different policy agents and policy support measures. Each system diagram is complemented by a risk “heat map” which provides a qualitative assessment of risk allocation across different stakeholders.

Figure ES2: **Map of the nuclear power plants analysed in this publication**

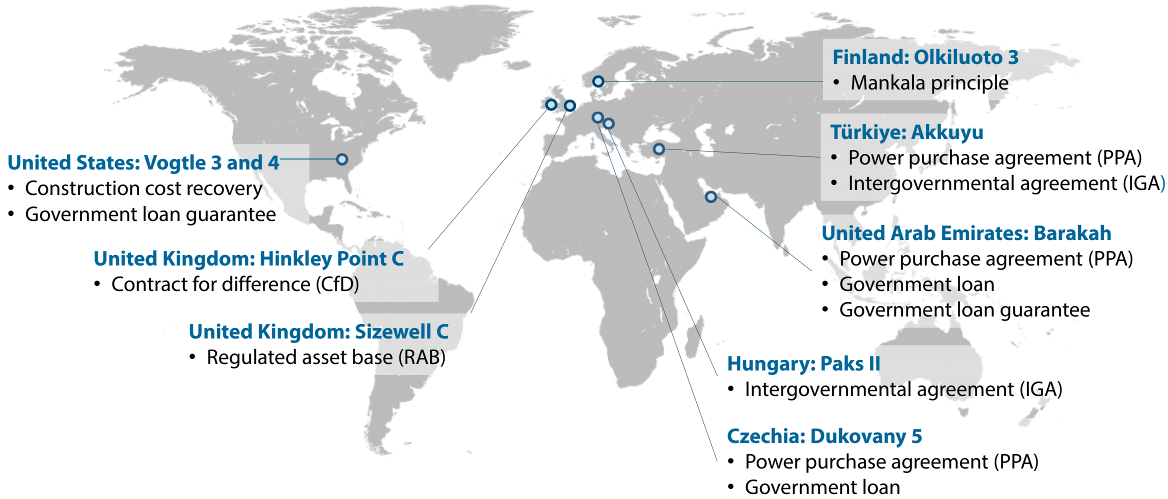



Table ES1: **Summary of the nuclear power plants analysed in this publication**

| | Olkiluoto 3 | Vogtle 3 and 4 | Barakah | Akkuyu | HPC | Sizewell C | Paks II | Dukovany |
|---|---|---|---|---|---|---|---|---|
| Country | Finland | United States | United Arab Emirates | Türkiye | United Kingdom | United Kingdom | Hungary | Czechia |
| Status | Operational | Operational (partial) | Operational | Under construction | Under construction | Pending final investment | First concrete planned 2024 | Preferred bidder selected |
| Construction year | 2005 | 2013 | 2012 | 2018 | 2016 | 2025 (expected) | 2024 (expected) | 2025 (expected) |
| Reactor technology | EPR | AP-1000 | APR-1400 | VVER-1200 | EPR | EPR | VVER-1200 | APR-1000 (expected) |
| Capacity | 1.6 GWe | 2.2 Gwe (2 units) | 5.6 Gwe (4 units) | 4.8 Gwe (4 units) | 3.2 Gwe (2 units) | 3.2 Gwe (2 units) | 2.4 Gwe (2 units) | 22 GWe (2 units – expected) |
| Owner(s) | TVO | Georgia Power | ENEC | Rosatom | EDF | EDF, UK Gov., TBD | Hungarian Gov. | ČEZ |
| Financing model | Mankala principle | Construction cost recovery, loan guarantee | PPA, government loan and guarantee | PPA, inter-governmental agreement | Contract for difference (CfD) | Regulated asset base (RAB) | Inter-governmental agreement | PPA, government loan |
| Debt-to-equity ratio | 75:25 | 0:100 | 80:20 | n/a | 0:100 | TBD | 80:20 | 98:2 (expected) |

Taken together, the NEA nuclear financing case studies highlight that a range of financing models have been implemented or are being considered for nuclear new build, leading to different roles for public and private stakeholders and different allocations of key project risks across stakeholders, particularly market risks and construction risks.

These results are relevant to policymakers, financiers and the broader nuclear sector in countries that seek to expand the role of nuclear energy and are reviewing their options to address the challenge of financing a tripling in global nuclear energy by 2050.

## Key insights on nuclear financing frameworks

The nuclear financing case studies provide several key insights on the drivers and key features of different financing frameworks that have been implemented in recent years for nuclear new build projects. Building on these key findings, four Key insights emerge that should be carefully considered upfront for all future nuclear energy projects.

### 1. Financing frameworks remain closely linked to national and industrial contexts

Financing frameworks do not exist in a vacuum. Rather, they are deeply intertwined with national and industrial contexts. From a policy perspective, this means that lessons learnt need to be contextualised before they can be transferred to another setting. To do so requires a solid understanding of how a financing framework connects to policy and industrial environments.

### 2. Financing frameworks cannot solve structural problems caused during upfront project planning

A long-term national commitment to nuclear energy and strong upfront project planning are necessary conditions for devising and implementing successful frameworks for nuclear financing. Consequently, when a nuclear energy project fails to reach a final investment decision it may not necessarily be because there is a specific challenge or roadblock with financing *per se* but rather because discussions about nuclear financing unearthed more systemic issues with the project that need to be addressed first.

### 3. De-risking construction is key to attracting additional sources of funding and to reducing the cost of capital

Among the different risks facing nuclear new build projects, those associated with construction cost overruns, delays and completion are the most significant. Consequently, these types of risks deserve the most attention when discussing the merits of different nuclear financing frameworks.

However, tackling construction risks implies some trade-offs. In particular, the case studies demonstrate the need to balance the ability to mitigate those risks before construction and the ability to absorb them during construction.

On the one hand, financing frameworks should create incentives for stakeholders to minimise risks prior to construction, focusing in particular on those stakeholders that are best placed to do so. On the other hand, if risks do materialise during construction, financing frameworks should clearly account for the ability of different parties to face these risks and absorb them financially.

One key insight is consistent across all the case studies in this publication: ultimately, all risks are largely born by rate payers, i.e. consumers, and/or taxpayers, i.e. governments. Moreover, rate payers and taxpayers are ultimately best placed to absorb low-probability risks with high impacts, such as construction cost overruns.

### 4. Aligning stakeholders' interests should remain an overarching principle

The importance of allocating risks between parties should not distract from the overarching objective of aligning stakeholders' interests. Nuclear energy involves significant financial, safety, environmental and geopolitical considerations, making it essential to engage over a long period a diverse set of stakeholders, including governments, safety authorities, local communities and investors.

While a key aspect of nuclear financing frameworks is to formulate clear decisions about risk allocations, this process should be implemented in a way that keeps in sight the need to ultimately align stakeholders' interests through efficient contracting. Doing so is an essential condition for overall project success and should therefore remain a key consideration when discussing the relative merits of different nuclear financing models.

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IEA (2024b), *World Energy Investment 2024*, IEA, Paris, www.iea.org/reports/world-energy-investment-2024.

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# Chapter 1. Introduction: Presentation of the NEA methodology to assess nuclear financing frameworks and overview of the case studies

This publication provides an in-depth review of a range of financing frameworks and strategies that have been implemented or are presently under consideration for nuclear new build projects around the world. To conduct this review, the NEA developed a methodology to compile, synthesize and analyse publicly available information. Eight case studies are presented in this publication.

The case studies provide source of information about the drivers and features of recent nuclear financing models and present the characteristics of each case study in a system diagram format that facilitates understanding and analysis. The results are relevant to policymakers as well as financiers and the broader nuclear sector. This approach establishes a common vocabulary and the basis for comparative analysis in order to identify and discuss key lessons learnt about the relative merits of different strategies to finance nuclear projects.

## Case studies methodology and outline

The NEA developed a methodology for the review of financing frameworks that is applied consistently in eight case studies of nuclear new build projects.

Each case study strives to provide a practical understanding of the financing framework and policy measures that were or will be implemented to support the project, and follows the following outline:

- **Background**: This section provides an introduction about the project and an overview of how the discussions about the project took place and evolved at the national level.
- **Timeline**: This section details key events during the project decision and implementation processes, focusing on legislative, regulatory and construction milestones as well as decisions about financing.
- **Financing framework**: This section compiles publicly available information about the financing framework and presents the financing framework in a system diagram. The system diagrams clearly identify the roles of the different stakeholders, sources of equity and debt financing, revenue streams, as well as the role of different policy agents and policy support measures.
- **Risk allocation**: To complement the system diagram, this section provides a risk "heat map" that assesses qualitatively how risks were allocated across different stakeholders. The heat maps can be understood as the risk fingerprint for each system diagram and its corresponding financing framework.
- **Role of government**: This section summarises and highlights the role of government in respective projects.

## Case studies approach to risk allocation

Each case study includes comprehensive analysis to assess the allocation of risk across stakeholders. The analysis relies on publicly available and verifiable information. The NEA further engaged with relevant stakeholders, including project-level stakeholders and government officials, to gather their perspectives on risk allocation. This engagement process allowed the NEA to capture nuances about risk allocation decisions that would otherwise not be evident from publicly available information.

Nuclear new build projects face multiple risks during the life cycle of the plant. Those risks can be organised and reported in different ways and there does not exist in the current literature one reference approach to build upon. For each case study presented in this publication, the different risks are therefore consolidated into five categories that aim to represent the range of risks that have been reported for nuclear new build projects:

i. **Political and regulatory risks**: Nuclear power projects can face unique political and regulatory risks, particularly related to changes in policies or changes in regulation, which may result in forced project abandonment prior to commissioning or premature early closure of operating nuclear plants.

ii. **Construction risks**: A range of project management, supply chain and workforce challenges can be encountered during the building phase of a nuclear power project, leading to costs overruns, delays and, potentially, to the project not being completed. Challenges meeting nuclear quality standards or regulatory standards are also considered in this risk category.

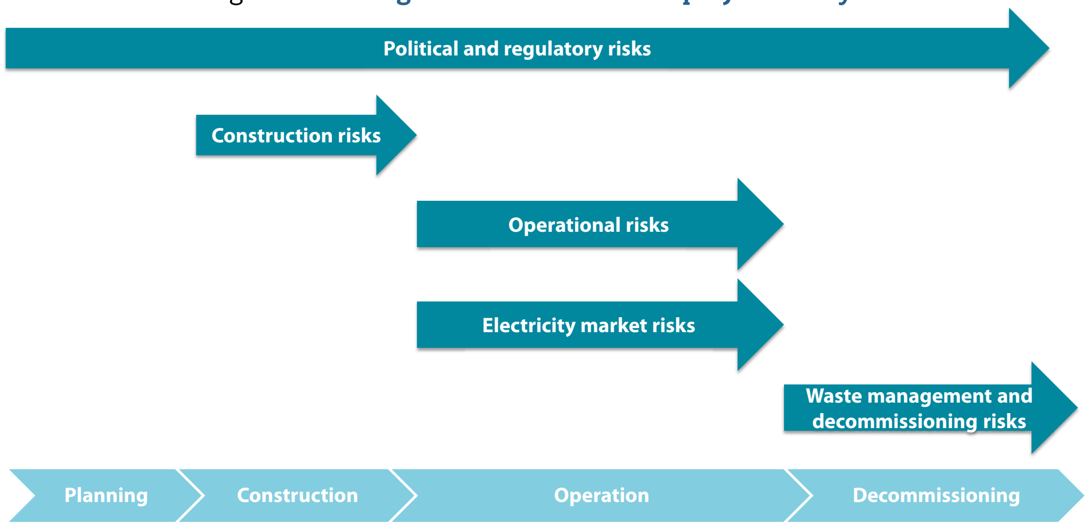
iii. **Operational risks**: Unexpected operational difficulties can result in lowered electrical output (i.e. reduced load factor), extended outages, additional repairs and maintenance, and other challenges.

iv. **Electricity market risks**: Uncertainties in the electricity market and revenue generation for nuclear power projects can occur in both the short and the long terms. This category of risk further includes revenue risks in regulated market environments where decisions by public utility commissions can impact project profitability.

v. **Waste management and decommissioning risks**: Challenges can arise associated with the safe and effective management of nuclear waste and the decommissioning of nuclear facilities. This includes technical, regulatory or political delays to establish spent fuel management and waste management approaches, and to implement long-term solutions for high-level nuclear wastes, including deep geological repositories.

These categories of risk will impact different periods of the project life cycle. As shown in Figure 1.1 below, political and regulatory risks will apply throughout the project life cycle, whereas the other risk categories will apply during some periods of the project life cycle more than others.

Figure 1.1: **Categories of risk over the project life cycle**



## Boundary conditions for the case studies

The methodology developed in this report aims to strike a balance between two objectives: (i) providing an assessment of recent frameworks and strategies for the financing of nuclear new build; and (ii) ensuring that the content remains accessible and useful for policymakers. To strike this balance, the following boundary conditions were established for the scope and content of the case studies:

- **Publicly available information**: This report is based on publicly available information. Commercially sensitive and confidential information that cannot be backed by a reference available in the public domain is not included.
- **Snapshot in time**: The methodology provides a snapshot in time of project financing frameworks. As much as possible, the case studies are based on the financing frameworks at the time of the final investment decision. When projects have not yet reached the final investment decision, the latest publicly available information is reported. Changes to the financing framework during construction (unless significant) or refinancing, when projects reach commercial operation, are not discussed.
- **Level of detail about financing frameworks**: The case studies consider project-level information and do not include financing arrangements at the level of equity investors' balance sheets. For example, specific details on how debt financing would be raised by strategic equity investors, such as utilities, are beyond the scope of this publication.
- **Risk categories**: The publication analyses risk allocation in five categories of risk. It does not attempt to break down these risks into sub-categories. While doing so would provide additional valuable information, it would in practice often face limitations due to the level of reporting of information available in the public domain.
- **Risk distribution**: For each category of risk, the case studies present an assessment of the overall exposure of the different stakeholders. Conversely, the publication does not attempt to provide an assessment of the risk distribution, nor does it try to tie different degrees of risk exposure to the risk distribution. This is an area of limitation as, for example, the allocation of residual risks can be of significant importance to the overall financing framework. Residual risks are defined as the risks that a project would still bear after risk mitigation strategies have been implemented. In practice, these risks often correspond to low probability but high impact risks. When publicly available for a given case study, information on residual risks is presented qualitatively as part of the discussion on risk allocation.

## Case studies overview

In this report, eight nuclear power plants across three continents and seven countries have been reviewed in the order of project announcement. Figure 1.2 and Table 1.1. below summarise some of the key information regarding the projects in this publication.

The case studies include three projects in operation (Olkiluto 3, Finland; Vogtle 3 and 4, United States; Barakah, United Arab Emirates), two projects under construction (Akkuyu, Türkiye; Hinkley Point C, United Kingdom), one project that has reached a final investment decision but where construction has not started yet (Paks II, Hungary), and three projects that have yet to reach final investment decisions (Sizewell C, United Kingdom; and Dukovany, Czechia).

These projects cover a range of different approaches to nuclear financing that combine a range of policy measures and sources of funding. Each project is unique in terms of its approach to financing. Nevertheless, the eight projects can broadly speaking be grouped into four main categories:

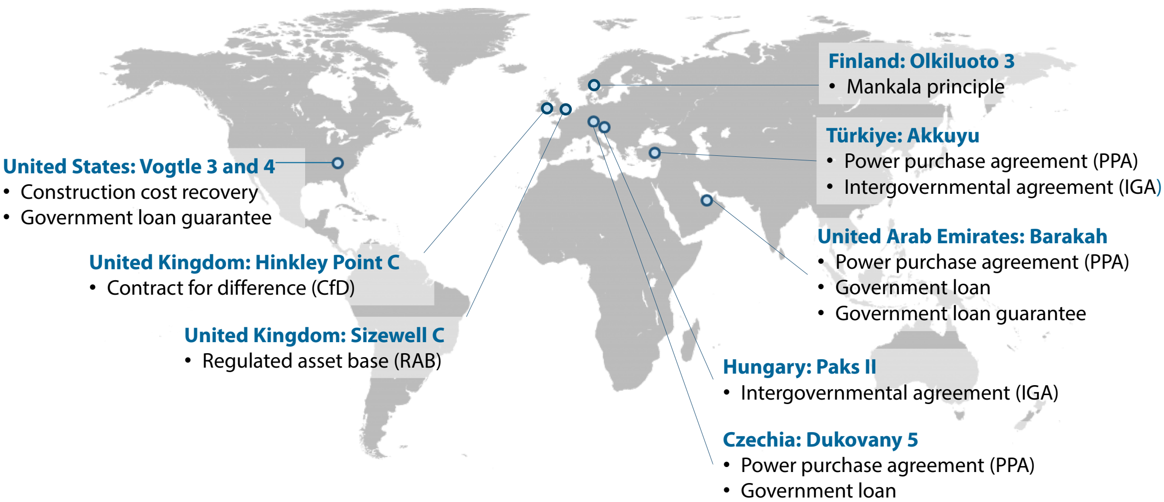
i. **Regulated revenues**: Akkuyu, Barakah, Dukovany and Hinkley Point C are projects whose financing is underpinned primarily by mechanisms to regulate revenues through power purchase agreements (for the first three projects) or a contract for difference for Hinkley Point C.

ii. **Cost recovery regulation**: Vogtle 3 and 4 and Sizewell C are based on specific regulated frameworks for costs recovery. Vogtle 3 and 4 are financed primarily under a construction costs recovery regulation. Sizewell C is expected to implement a regulated asset base (RAB) model.

iii. **Co-operative model**: Olkiluoto 3 in Finland is based on the Mankala model, whereby the power utility sells its produced electricity to its shareholders at production costs.

iv. **Vendor financing**: In the case of the Paks II project in Hungary, the financing framework relies primarily on vendor financing with debt financing from the vendor country (Russia) to cover 80% of the financing needs.

Figure 1.2: **Map of the nuclear power plants analysed in this publication**

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|---|---|---|---|---|---|---|---|---|
| Country | Finland | United States | United Arab Emirates | Türkiye | United Kingdom | United Kingdom | Hungary | Czechia |
| Status | Operational | Operational (partial) | Operational | Under construction | Under construction | Pending final investment | First concrete planned 2024 | Preferred bidder selected |
| Construction year | 2005 | 2013 | 2012 | 2018 | 2016 | 2025 (expected) | 2024 (expected) | 2025 (expected) |
| Reactor technology | EPR | AP-1000 | APR-1400 | VVER-1200 | EPR | EPR | VVER-1200 | APR-1000 (expected) |
| Capacity | 1.6 GWe | 2.2 Gwe (2 units) | 5.6 Gwe (4 units) | 4.8 Gwe (4 units) | 3.2 Gwe (2 units) | 3.2 Gwe (2 units) | 2.4 Gwe (2 units) | 22 GWe (2 units – expected) |
| Owner(s) | TVO | Georgia Power | ENEC | Rosatom | EDF | EDF, UK Gov., TBD | Hungarian Gov. | ČEZ |
| Financing model | Mankala principle | Construction cost recovery, loan guarantee | PPA, government loan and guarantee | PPA, inter-governmental agreement | Contract for difference (CfD) | Regulated asset base (RAB) | Inter-governmental agreement | PPA, government loan |
| Debt-to-equity ratio | 75:25 | 0:100 | 80:20 | n/a | 0:100 | TBD | 80:20 | 98:2 (expected) |

# Chapter 2. Nuclear financing case studies

## Olkiluoto 3 project

### *Background*

Olkiluoto 3 is the fifth nuclear power plant unit in Finland and the first European Pressurised Reactor (EPR) to be built, with a capacity of 1 600 MWe. TVO is the operator and licensee of the three units in Olkiluoto. It is a non-listed public company owned by a consortium mainly comprised of Finnish power and industrial companies.

In 2003, a consortium led by Areva (66%) and Siemens (34%) was selected to construct the nuclear power plant under a fixed price scheme. Olkiluoto 3 was originally scheduled to be operational in 2009 but has experienced major construction delays of over a decade. As of May 2023, the third Olkiluoto unit has finally entered commercial operations after a 14-year delay.

The project witnessed substantial delays due to technical reasons, being a first-of-a-kind (FOAK) reactor project, and this resulted in construction cost overruns (SFEN, 2018). Estimations suggest the total cost to have ballooned to EUR 11 billion, significantly above the initially agreed EUR 3.2 billion contract (Euractiv, 2020). TVO estimated in its annual report that its portion of the total cost alone would reach EUR 5.8 billion (TVO, 2023).

### *Timeline*

The timeline for Olkiluoto 3 includes:

- **2000**: TVO submitted an application for an additional nuclear capacity construction to the Council of State.
- **2002**: The Finnish government issued a decision in principle for the construction of a new nuclear power plant unit and the decision was ratified by Parliament.
- **2003**: TVO signed the contracts with the consortium between Areva (66%) and Siemens (34%) for a new EPR unit under a fixed price turnkey scheme.
- **2005**: A construction licence was granted by the Finnish government and the construction of the unit started.
- **2015**: Areva went through major restructuring plans and received capital injection.
- **2019**: TVO was granted the operating licence of Olkiluoto 3.
- **2023**: Commercial operation started.

### *Financing framework*

The Olkiluoto 3 project financing framework is based on the Finnish Mankala principle that underpins the investment of electro-intensive end-users.

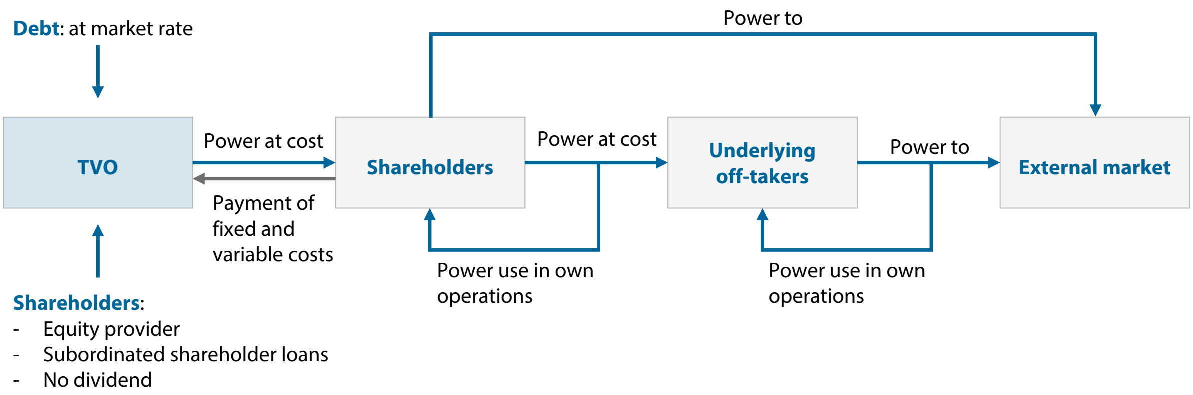
#### *Mankala principle*

The Mankala principle is a commonly used ownership arrangement in the Finnish energy industry where several parties join resources to acquire and co-own an asset. The model embodies characteristics of a hybrid model between corporate and project financing. Financing of projects is undertaken on the balance sheet of the Mankala company; however, the ownership of individual assets varies depending on the specific project.

Unlike typical commercial companies, a Mankala company does not generate profit or distribute dividends to its shareholders. Instead, shareholders are offered the right to purchase generated electricity at cost and are obligated to cover expenses proportionate to their respective ownership. The allocated electricity, in turn, may be used for self-consumption or sold through either bilateral agreements or the exchange market, depending on the needs of the co-owner. Today, more than half of the national electricity production in Finland is produced at cost price through the financing mechanism of the Mankala principle.

One of the key features of the Mankala principle is the sharing of the risks of large-scale projects among multiple investors and customers. This enables regional utilities and small power companies to pool resources to participate in capital-intensive projects and capitalise on economies of scale. This approach provides a viable opportunity for small stakeholders who lack the capacity to operate a project independently or invest in large production units. For large industrial consumers, the Mankala principle is a means to ensure a secure supply of electricity with a long-term price that is unaffected by price volatility in the wholesale market. The strategy also enhances valuation by rating agencies, as a long-term PPA with a sizeable customer base provides a stable prospective revenue stream from the project.

Figure 2.1: **Mankala principle operating model**




*Equity investment from industrial end-users*

The shareholders of TVO agreed on an increase in capital mounting up to 15-30% of the total cost of the new reactor through the issuance of fresh equity (EC, 2008). The company issued a new series of shares (B Series) to support the equity funding of the plant construction. TVO shareholders agreed upon signing the subscription agreement and undertaking for B series shares of Olkiluoto 3 and the shares were issued up to 2011.

Although a private company, TVO operates on a non-profit basis. In lieu of disbursing dividends to its shareholders, TVO directs its efforts towards providing a steady supply of electricity to its shareholders at cost. This arrangement effectively provides shareholders a tax exemption on dividend distribution.

The B series shares grant the right to procure electricity generated at Olkiluoto 3, as opposed to A series shares, which grant the right to electricity generated at OL1 and OL2. The shareholders in both share series that are essentially identical, with similar ownership proportions across the board. Shareholders hold offtake rights to the electricity generated at Olkiluoto Nuclear Power Plant in proportion to their ownership in the project, with the same electricity price (TVO, 2023).

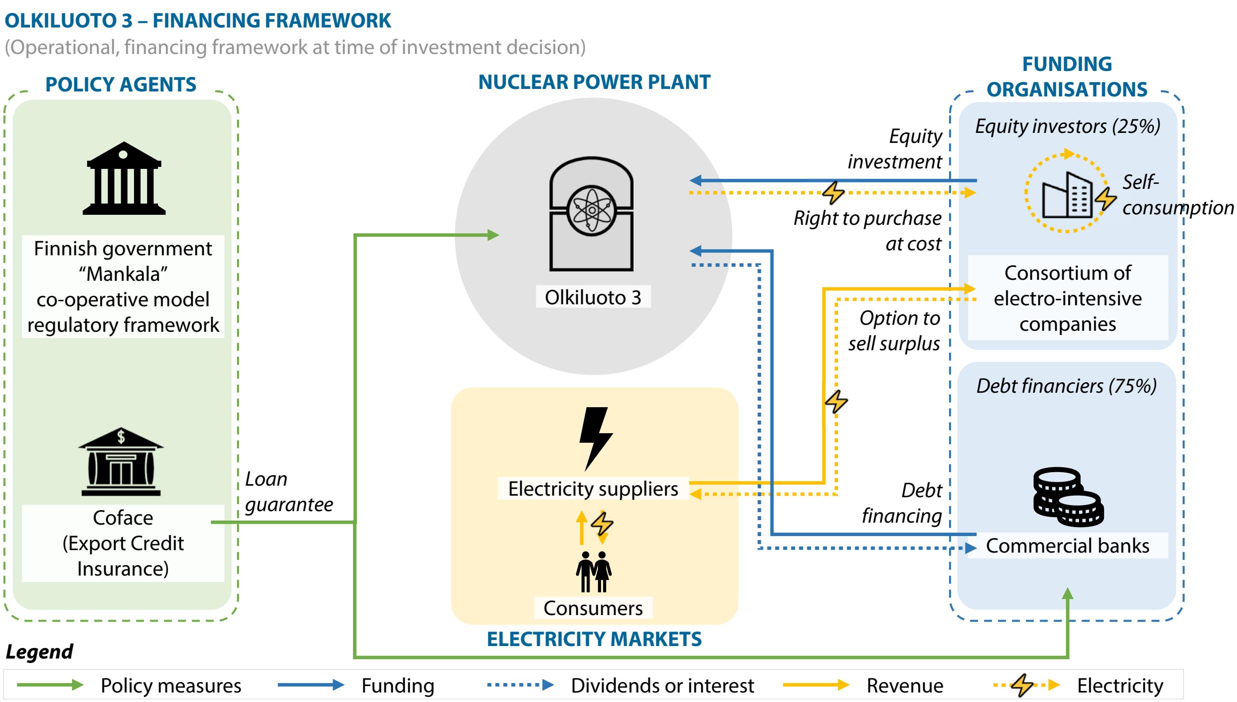
*Debt financing and export credits*

In addition to equity capital, the shareholders provided an additional subordinated loan that amounted to about 5% of the total cost. TVO also arranged a credit facility and a series of bilateral loans with outside stakeholders. Some of this debt was later refinanced through a EUR 570 million loan guaranteed by Compagnie française d'assurance pour le commerce extérieur (Coface), the French export credit agency. On behalf of the French government, Coface provided loan guarantees on the debt financing as part of its export credit insurance activities (EC, 2008).

The credit facility was granted to TVO by a banking syndicate in which BLB, BNP Paribas, JP Morgan, Nordea and Svenska Handelsbanken were the mandated lead arrangers. The five banks each undertook to provide up to EUR 500 million, adding up to EUR 2.5 billion in total. In the course of the syndication process, however, other banks participated in the credit facility, and in the end 12 banks participated on equal terms. The initial contract between TVO and the financers amounted EUR 1.95 billion, but was later reduced to EUR 1.35 billion after TVO secured the guaranteed loan from Coface. In addition to other financing, TVO finalised an additional credit facility of EUR 1.6 billion on the back of more favourable market conditions and TVO did not call on the new credit facility (EC, 2008).

As the project faced costs overruns and delays, TVO shareholders provided during the project EUR 750 million additional shareholder loans in total in order to support the project completion.

Figure 2.2: **Financing framework for the Olkiluoto 3 project**




## *Risk allocation*

Overall, the risks associated with the Olkiluoto 3 project are dispersed among various parties, with each party responsible for their share of the expenses and liabilities.

- **Political and regulatory risks**: The Finnish government provided the policy and legal framework, the Mankala principle, for the construction of the new unit. Before making the final decision, the government held consultations with the general public to gather their viewpoints regarding the new unit build. In 2002, the decision in principle was granted and ratified by Parliament alongside an environment impact assessment (Sandberg and Tiippana, 2005). The Finish government decision in principle provides protection again potential changes in policy that would lead to the project being terminated, meaning that the government bears the majority of this risk. Conversely, no special provisions exist regarding risks related to changes in nuclear safety regulation, which is therefore carried by the equity provider.

- **Construction risks**: The Olkiluoto 3 construction contract was agreed upon a fixed price turnkey basis with the consortium of Areva and Siemens. The consortium was to bear the majority of the construction completion responsibility at its own risk. According to the director of legal affairs of TVO, the company had initially signed the plant supply contract noting that the supplier would be the party responsible for any delays and resulting costs (Yle, 2013). The equity providers, however, remained partially exposed to risks associated with construction delays and cost overruns, which were not directly under the oversight of the Areva-Siemens consortium. As the project faced cost overruns and delays, both Areva-Siemens and TVO filed several claims for compensation. Those were eventually settled in 2018 following an international arbitration ruling (WNN, 2018).

  Due to various unexpected delays and considerable cost overruns, Olkiluoto 3 was 14 years behind schedule and the total estimated project cost was EUR 8 billion higher than initial projections (NEA, 2020). In the meantime, the contractors went through major turbulence with growing financial burdens. The Areva-Siemens consortium did not deliver the project on the original schedule and was consequently involved in legal disputes with TVO, with both sides claiming large levels of compensation against each other.

  Areva eventually opted to write down provisions from its accounts by a minimum of EUR 2.7 billion (IAEA, 2014). In 2017, Areva underwent a major restructuring process as the French government bought out minority shareholders and delisted the group. Furthermore, the French government provided recapitalisation funding of EUR 4.5 billion to Areva. The capital injection was intended to address the accumulated losses of the company, and to mitigate significant risks associated primarily with the Olkiluoto project (EC, 2018).

- **Operational risks**: The operational risks associated with Olkiluoto 3 primarily rest with TVO and shareholders based on the Mankala cost coverage structure. These risks are effectively dispersed among the company's 60 or more direct and indirect shareholders. Each shareholder assumes responsibility for the annual expenses and associated risks, with both being limited to the shareholder's proportionate ownership in the company.

  As TVO is a not-for-profit entity and provides electricity to its shareholders at cost, all annual expenses related to Olkiluoto 3 are covered by its shareholders. Each shareholder, respective to the power consumption or transfer to the company, must bear the proportionate variable annual costs.

- **Electricity market risks**: The risks pertaining to the market are assumed by the equity providers. TVO is a non-profit entity that provides electricity at cost to its members. As such, the company does not assume electricity market risks and, rather, the operational costs are the responsibility of its shareholders. In the face of market volatility, the shareholders are expected to absorb the risk.

  Depending on their main business and services, the equity providers may exercise the option to either utilise the electricity for their own consumption, supply it to their local communities, or sell it on the open market. With this difference in business model, the risk-taking scheme of each equity provider may vary. If the equity provider consumes the allocated offtake, it would bear the market risk. On the other hand, if it opts to sell the electricity to the external market, the risk may be factored into the adjusted electricity prices passed on to the buyers.

- **Decommissioning and waste management risks**: Under the current Finnish Nuclear Energy Act, TVO is responsible for the waste management (TVO, 2023). Finnish authorities set the annual fee that nuclear operators have to pay to the National Nuclear Waste Management Fund to ensure that it can cover the costs associated with nuclear waste management. As such, the fund is fully funded by the producers of nuclear waste. As in the case of Olkiluoto 3, all expenses regarding radioactive waste management including spent fuel and decommissioning are part of the fixed operation and maintenance cost. Equity providers of TVO are held accountable for costs incurred by TVO's annual costs which includes nuclear waste management. As such, the risk and expenses of decommissioning and waste management is dispersed among the shareholders of Olkiluoto 3.

Figure 2.3: **Allocation of key project risks for the Olkiluoto 3 project**

| | | Political and regulatory | Construction | Operational | Electricity market | Decommissioning and waste management |
|---|---|---|---|---|---|---|
| **Operator** | TVO | No exposure | No exposure | High | No exposure | No exposure |
| **EPC/vendor** | Areva-Siemens | No exposure | High | No exposure | No exposure | No exposure |
| **Equity providers** | Consortium of electro-intensive companies | Moderate | Moderate | Moderate | High | High |
| **Debt providers** | Coface, Commercial banks | No exposure | Low | Low | No exposure | No exposure |
| **Government** | Finnish Government | High | No exposure | No exposure | No exposure | Low |
| **Consumers** | - | No exposure | No exposure | No exposure | No exposure | No exposure |

*Legend: Level of risk exposure* — High — Moderate — Low — No exposure — Not applicable

## *Role of government*

The involvement of the Finnish government was limited in the Olkiluoto 3 project. Aside from setting the political and legal framework within its borders, the government did not provide any financial investment. Instead, the government sought to provide an enabling framework through the Mankala principle, which facilitated private sector financing from electro-intensive end-users.

## Vogtle units 3 and 4 project

### *Background*

The Vogtle Nuclear Power Plant is located in the state of Georgia, United States, and is the site of two existing reactors that were built in the 1980s (Vogtle 1 and 2). Two additional units (Vogtle 3 and 4) about 1 117 MWe each, are under construction based on the Westinghouse AP1000 design. This nuclear energy facility is owned by four entities, the Georgia Power Company (Georgia Power, 45.7%), Oglethorpe Power Corporation (OPC, 30%), Municipal Electric Authority of Georgia (MEAG Power, 22.7%), and Dalton Utilities (1.6%). The plant is operated by Southern Nuclear Operating Company, which is an affiliate of Georgia Power.

Figure 2.4: **Ownership breakdown of Vogtle units 3 and 4**

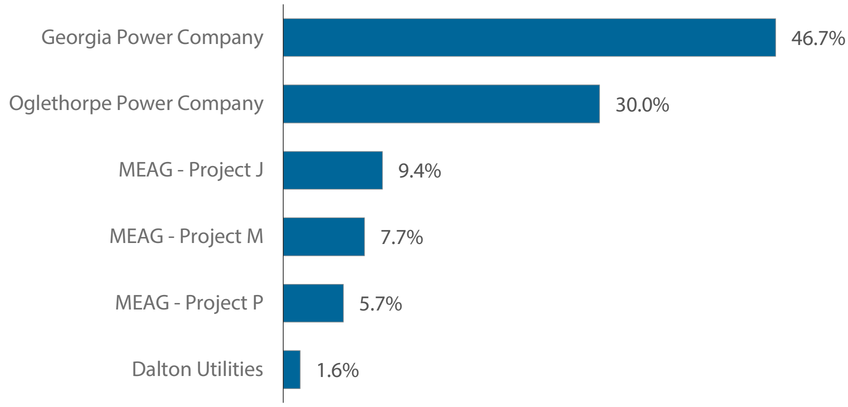



Table 2.1: **Presentation of Vogtle units 3 and 4 owners**

| | |
|---|---|
| **Georgia Power Company** | Georgia Power is a public utility company providing electric service to retail and wholesale customers. Georgia Power, and Southern Nuclear Operating Company (Southern Nuclear), the operator of the Vogtle plant, are both subsidiaries of the Southern Company. |
| **Oglethorpe Power Company** | OPC is a not-for-profit, Georgia-based electric membership corporation owned by 38 retail electric distribution co-operative members serving approximately 4.4 million people. |
| **Municipal Electric Authority of Georgia** | MEAG Power is a not-for-profit generation and transmission organisation providing wholesale electricity to 49 member communities who operate local electric distribution systems. The company holds ownership of the Vogtle units 3 & 4 through 3 separate SPVs. |
| **Dalton Utilities** | Dalton Utilities is a public company providing various utility services to the City of Dalton in Georgia. Dalton Utilities does not publish a public report of its financial results. |

The Vogtle 3 and 4 units were the first nuclear new build projects in the United States in over three decades. The units were initially scheduled for commercial operation in 2016 and 2017, respectively. However, the Vogtle 3 and 4 project faced significant construction delays and cost overruns. According to Bloomberg, the initial budget of USD 14.3 billion has more than doubled, with costs overruns as of 2023 exceeding USD 16 billion (Bloomberg, 2023). These costs overruns can be primarily explained by a lack of design maturity when construction started, challenges with supply chain capabilities and project management, and changes in regulatory requirements (NEA, 2020).

### *Timeline*

The timeline for the Vogtle 3 and 4 project includes:

- **2002**: The US Nuclear Regulatory Commission (NRC) began its certification of the AP1000 design.
- **2008**: Georgia Power, on behalf of its co-owners, entered a fixed price Engineering Procurement Construction (EPC) contract with Westinghouse Electric Company (Westinghouse) and Stone & Webster Inc., both entities at the time owned by the Shaw Group LLC.
- **2009**: The NRC issued Vogtle an early site permit and limited work authorisation.
- **2011**: The design certification of AP1000 was delayed and the Shaw Group divested its shares in Westinghouse, which was taken over by Toshiba.
- **2012**: The combined licence (COL) was issued by the NRC for Vogtle units 3 and 4 and the Shaw Group was acquired by Chicago Bridge & Iron (CB&I).
- **2013**: Construction started for Vogtle units 3 and 4.
- **2016**: Westinghouse acquired the nuclear construction unit of CB&I Stone & Webster Inc.
- **2017**: Westinghouse filed for bankruptcy and Bechtel Power Corporation (Bechtel) was appointed as the new primary contractor.
- **2020**: An operator licence was granted for Vogtle unit 3.
- **2023**: Vogtle unit 3 began commercial operation.
- **2024**: Vogtle unit 4 began commercial operation.

### *Financing framework*

The Vogtle Nuclear Power Plant was funded by a utility consortium through equity financing. While debt was not raised at the project level, the four shareholders of Vogtle 3 and 4 raised debt that enabled the project at the level of the corporate balance sheets. The four entities that jointly own Vogtle units 3 and 4 have varied corporate structures and thus have developed distinct strategies to address their respective financing requirements. While Georgia Power had enough resources to handle the cost overruns, the other co-owners had limited ability to absorb the rising construction expenses and had to explore alternative methods to support the project's financing during the construction period.

At the federal level, the US government provided indirect financial aid through a range of support mechanisms, as outlined in the 2005 Energy Policy Act, that would benefit the Vogtle project both before and after the start of commercial operations:

- **During construction**, Vogtle was able to benefit from the loan guarantee support from the US Department of Energy (DOE) alongside the Federal Financing Bank (FFB) loans.
- **After construction**, Vogtle is able to benefit from the production tax credit, which would work similarly to a subsidy per unit of output (NEA, 2015).

At the state level, the Georgia legislature introduced the 2009 Nuclear Energy Financing Act to enable Nuclear Construction Cost Recovery (NCCR) tariffs for investor-owned utilities such as Georgia Power. The NCCR is akin to Construction Work in Progress (CWIP) and allows for financial costs to be recovered during construction through consumers' electricity bills.

*US DOE loan guarantees*

Georgia Power, OPC and the three subsidiaries of MEAG Power were issued up to USD 12 billion in loan guarantees from the US Department of Energy pursuant to the programme established under Title XVII of the Energy Policy Act of 2005 (Title XVII Loan Guarantee Program). The initial loan agreements were executed in 2014 and 2015 and subsequently in March 2019. Under the DOE Loan Guarantee Agreement, Georgia Power, OPC and the MEAG Power subsidiaries were authorised to borrow loans through the FFB Credit Facilities up to USD 12 billion in total (US DOE, n.d.). The loan guarantee agreement allows Georgia Power to secure funds, which can be used to reimburse the costs they incurred for the construction of Plant Vogtle units 3 and 4. The interest rate was set taking into account the average yield on the US Treasuries of comparable maturity at the beginning of the interest rate period plus a spread of 0.375% (Southern Company, 2022).

*Production tax credit (PTC)*

The nuclear production tax credits were introduced through the 2005 Energy Policy Act to support advanced nuclear energy projects on a federal level. The credit was set at USD 18/MWh of electricity produced for the first 8 years of operations of new advanced nuclear facilities, up to 6 000 MW generating capacity nationwide (NEA, 2015). To be eligible for the credits, the plants were required to reach commercial operation by the end of 2020. Vogtle units 3 and 4 were initially planned to be in full commercial service by 2017 and were expected to benefit from this tax credit.

Although the Vogtle project underwent extensive delays and eventually failed to meet the proposed deadline, units 3 and 4 will be able to take advantage of the nuclear PTC due to the update in the programme. The US government signed the Bipartisan Budget Act of 2018 and provided an extension, allowing new reactors beyond the 2020 timeframe to qualify for the nuclear PTCs. In addition, the renewed mechanism allowed public entity partners of Vogtle units 3 and 4 (i.e. OPC and MEAG Power) to transfer and monetise the tax credit and eventually to reduce the cost of the project for customers (World Nuclear News, 2018; MEAG, 2022).

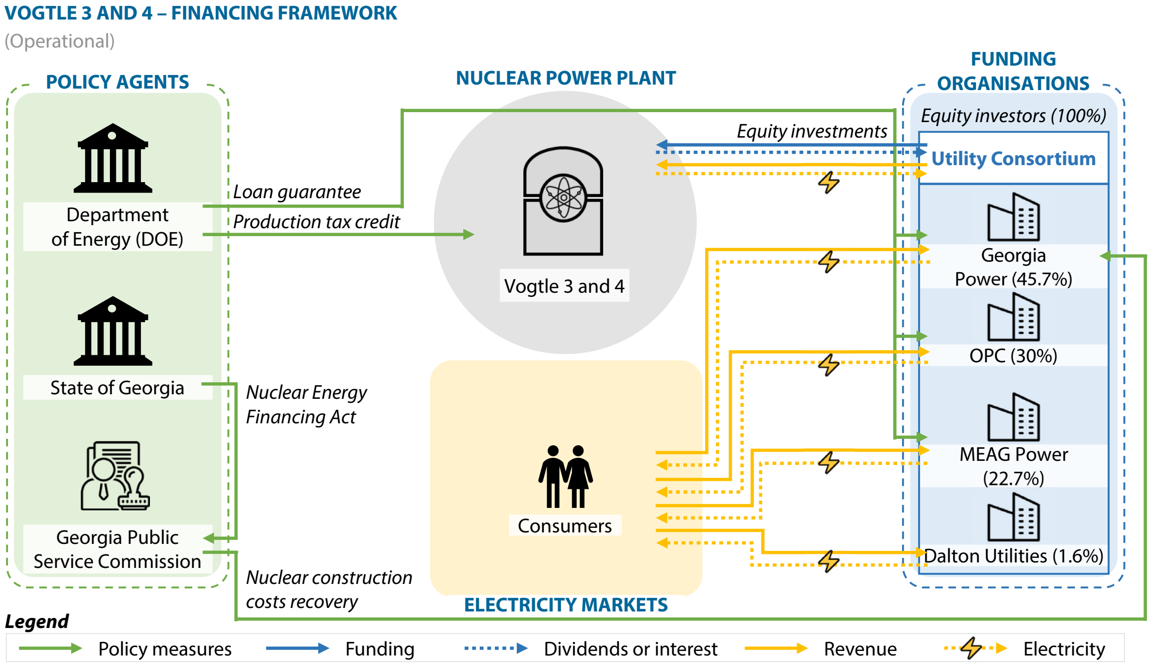
*Nuclear Construction Cost Recovery (NCCR) tariff*

Electricity utilities in Georgia can be divided into three categories: i) investor-owned utilities (Georgia Power), ii) municipally owned utilities (MEAG Power, Dalton Utilities), and iii) electric membership co-operatives (OPC). Investor-owned utilities are fully regulated by the Georgia Public Service Commission (PSC) whereas the latter two entities are not fully regulated. The Georgia PSC determines appropriate electricity rates and approves the utilities' resource management plans (Georgia PSC, n.d.).

The State of Georgia enacted in 2009 the Georgia Nuclear Energy Financing Act, which allows the early pass-through of financial costs of construction in the consumers' electricity tariff. The financing costs applicable to the NCCR must be reviewed and approved by the Georgia PSC before being recovered (General Assembly of Georgia, 2009). The law was repealed in 2018, meaning that it will not be applicable to projects other than Vogtle 3 and 4 (General Assembly of Georgia, 2018).

The NCCR tariff enabled Georgia Power to embed partial construction costs of the Vogtle project in the retail rates of residential consumers – in advance of the plant's commercial operations. As outlined in the Nuclear Energy Financing Act, the applicable surcharges were limited to a certified capital cost, approved by the Georgia PSC. Financing expenses beyond this threshold are to be recovered across the lifetime of the project. Through this system, Georgia Power continually paid off its debt during the construction phase and reduced the cost of financing (Southern Company, 2023).

Figure 2.5: **Financing framework for Vogtle units 3 and 4 project**




## *Risk allocation*

- **Political and regulatory risks**: Political and regulatory risks are primarily carried by equity investors and, to a lesser extent, the government and consumers. A number of measures at the Federal and State levels limit the exposure of equity investors to political and regulatory risks.

  At the Federal level, the government is engaged through supporting policy measures, financial incentives (DOE loan guarantees and tax credits) and setting long-term national energy strategies. In parallel, under the Energy Policy Act of 2025, the loan guarantees from the DOE will cover costs related to "A) *the failure of the [Nuclear Regulatory] Commission to comply with schedules for review and approval of inspections, tests, analyses, and acceptance criteria established under the combined license or the conduct of preoperational hearings by the Commission for the advanced nuclear facility; or (B) litigation that delays the commencement of full power operations of the advanced nuclear facility*" (US Congress, 2005). While the DOE loan guarantees will only be exercised in the event where the project defaults, the policy means that the US government will ultimately assume some of the political and regulatory risks associated with nuclear new build.

  In parallel, State-level policies play an important role as regulated tariffs mean that Georgia Power will be able to partially pass cost overruns related to political and regulatory factors to the final customers. This would imply the ability for investors to recover their costs from the consumers even in cases where changes of government policy result in the project being cancelled.

- **Construction risks**: The Vogtle construction risk allocation has been subject to several adjustments, influenced by changes in the project's schedule. Overall, the financial costs related to construction are primarily carried by consumers and partially by equity providers and EPC lead-contractors.

Initially, Georgia Power and its co-owners had signed a fixed price turnkey contract with Westinghouse and Stone & Webster Inc., where the two EPC contractors were responsible for the project as a whole package and the owners of Vogtle's exposure was insulated with the capped price (Reuters, 2017). However, due to financial difficulties faced by these partners, the contract was rearranged with Bechtel, which negotiated a cost reimbursable plus fee arrangement (Southern Company, 2017). Accordingly, the EPC exposure to construction risks can be considered to have been high for Westinghouse and Stone & Webster and then low for Bechtel.

The risk allocation of the project changed and is now shared between the EPC contractor and co-owners. Bechtel was offered to be reimbursed for actual costs plus a base fee and an at-risk fee, subject to adjustments based on performance against cost and schedule targets, while the co-owners were liable for the proportionate share of all amounts owed to Bechtel. Under the regulated tariffs framework in place in Georgia, Georgia Power can pass "reasonable" and "prudent" construction cost overruns to final consumers, as determined by the PSC after units 3 and 4 are fully constructed (S&P Global, 2019; Southern Company, 2019; Southern Company, 2023).

- **Operational risks**: All costs associated with operations and fuel are proportionally absorbed by the co-owners depending on their respective ownership in the project. While most of the risk is assumed by the equity providers, Southern Nuclear acts as the main operator. As the designated operator of the Vogtle units, the scope of work of Southern Nuclear includes licensing, engineering, procurement, contract management, construction and pre-operation services (OPC, 2023).

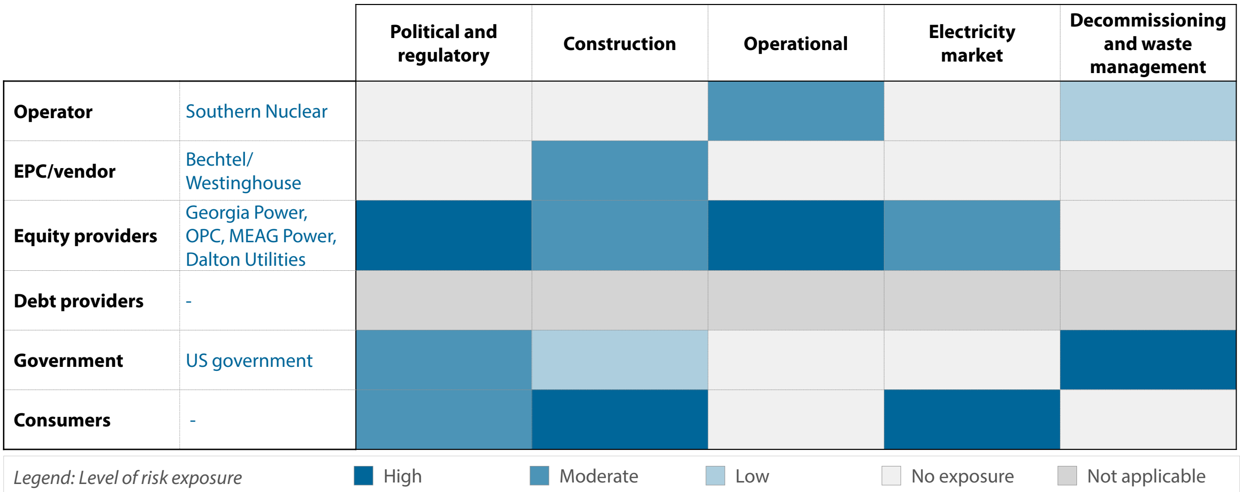
- **Electricity market risks**: Vogtle co-owners are able to hedge market volatility risks and pass through relevant costs to end consumers through electricity rate adjustments and long-term power contracts. Georgia Power has the ability to adjust electricity tariffs, though subject to negotiations with the Georgia PSC. The commission periodically updates permitted electricity tariffs for Georgia Power, which in turn allows the company to recoup its investment costs and maintain financial stability.

  OPC and MEAG Power have entered long-term contracts where offtakes will take off electricity at cost. OPC provides energy to its customers under long-term, take-or-pay wholesale power contracts and revises its tariffs as necessary to cover all costs of its system and financial costs (OPC, 2023). MEAG has also executed various take-or-pay power sales contracts with offtakers and participants (MEAG Power, 2022).

- **Decommissioning and waste management risks**: The NRC requires commercial nuclear power plant operators to set aside funds dedicated for future decommissioning. The funds are overseen by regulatory bodies including the NRC, the Federal Energy Regulatory Commission (FERC) and state PSCs, and are managed by third parties under investment guidelines to meet the owners' long-term financial commitments. Georgia Power, OPC and MEAG Power maintain external trust funds in line with NRC guidelines to fund their respective share of costs associated to decommissioning (Southern Company, 2022).

  Pursuant to the Nuclear Waste Policy Act of 1982, the US federal government takes the responsibility of the final disposal of commercial high-level radioactive waste. Under the act, nuclear facility owners and the DOE enter a disposal contract where the DOE provides permanent disposal of the spent nuclear fuel (OPC, 2023). The current framework includes a fee paid by the operator to the DOE and set at one USD per megawatt-hour.

Figure 2.6: **Allocation of key project risks for Vogtle units 3 and 4 project**




## *Role of government*

The US government's role in financing the Vogtle expansion project was relatively limited and the funding was mainly driven by market players. Yet, governments developed incentive programmes at both the Federal and State government levels.

On a Federal level, the US government passed the 2005 Energy Policy Act. This law worked as a platform for the government to provide indirect financing support, including loan guarantees alongside FFB loans. In addition, the Federal PTC was designed to function similarly to a subsidy to nuclear power plants, providing cash returns once commercial operations start. Finally, under the 1982 Nuclear Waste Policy Act the DOE is responsible for the management of high-level radioactive waste.

On the state regulatory level, the State of Georgia passed the Nuclear Energy Financing Act in 2009 and established the NCCR tariff. This mechanism allowed Georgia Power to continually pay off its debt and alleviate the financial burden pertaining to the construction of the project.

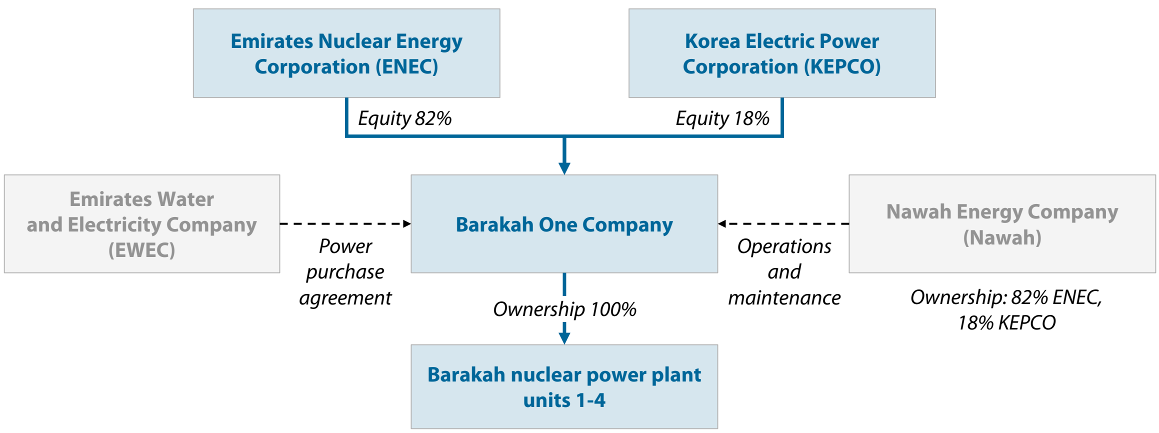
## Barakah project

### *Background*

The Barakah nuclear power plant is the first nuclear power plant built in the United Arab Emirates (UAE). The UAE Peaceful Nuclear Energy Program was established in 2008 following the launch of the UAE policy on civilian nuclear energy to meet the increasing demand of electricity and support the country's climate objectives. The government acted swiftly and established in 2009 the Emirates Nuclear Energy Corporation (ENEC) as the responsible entity for executing nuclear initiatives in the UAE. In that same year, the construction of Barakah was awarded to a Korean consortium led by Korea Electric Power Corporation (KEPCO).

Once fully operational, Barakah will serve 25% of the national electricity demand, powered by its four APR-1400 reactors with a total capacity of 5.6 GWe. The construction of the first unit started in 2012 and commercial operations commenced in 2021. The four units have been connected to the national grid.

Figure 2.7: **Structure of Barakah nuclear power plant ownership**




As outlined in Figure 2.7 above, ENEC owns the four units of the Barakah nuclear power plant through Barakah One Company. Nawah Energy Company (Nawah) holds the operating licence and is in charge of the operations and maintenance of the Barakah plant. Both Barakah One Company and Nawah are co-owned by ENEC (82%) and KEPCO (18%).

### *Timeline*

The timeline for Barakah includes:

- **2008**: The UAE government released a policy paper expressing the need for nuclear power to meet the country's growing energy needs.
- **2009**: The Federal Authority for Nuclear Regulation (FANR) and ENEC were established, and the Korean Consortium was selected for the construction of the new nuclear power plant.
- **2010**: The application for construction licences of Barakah plant units 1 and 2 was submitted.
- **2012**: Construction for Barakah plant unit 1 began.

- **2014**: The operating licence application to FANR for Barakah plant units 1 and 2 was submitted.
- **2016**: Barakah One Company was established to manage the commercial aspects of the Barakah project, and a PPA agreement was signed for the entire capacity of units 1 to 4.
- **2016**: Nawah Energy was established to operate and maintain the plant.
- **2021**: Commercial operation of Barakah plant unit 1 began.
- **2022**: Commercial operation of Barakah plant unit 2 began.
- **2023**: Commercial operation of Barakah plant unit 3 began.
- **2024**: Commercial operation of Barakah plant unit 4 began.

### *Financing framework*

The Barakah project was financed through a combination of equity commitments and loan facilities from various sources. The project followed a conventional approach in a regulated electricity market, and was financed by the host and exporting countries, with loan guarantees and a power purchase agreement (PPA) in place. The total estimated project financing of the nuclear power plant construction, as announced in 2016, is USD 24.5 billion, with an 80-20% debt-to-equity ratio (Bowen and Apostoaei, 2022).

#### *Power purchase agreement*

The sale of electricity generated at the Barakah nuclear power plant is managed by Barakah One Company. In 2016, Barakah One Company signed an exclusive PPA with the Emirates Water and Electricity Corporation (EWEC) to sell all the net electrical output of the Barakah nuclear power plant. EWEC is a wholly state-owned entity and is the sole buyer and seller of water and electricity in the Emirate of Abu Dhabi. It also supplies electricity to other Emirates within the UAE.

The two parties agreed on a fixed price-per-kilowatt structure of electricity generated by Barakah units 1 to 4 for the plant's entire 60-year lifetime. For the first five years after commissioning, the PPA price will reimburse the operating costs for Nawah. Thereafter, the PPA will be based on a target cost of operations to be reviewed every five years. Any operating costs exceeding the target are to be absorbed by Barakah One (IAEA, 2018).

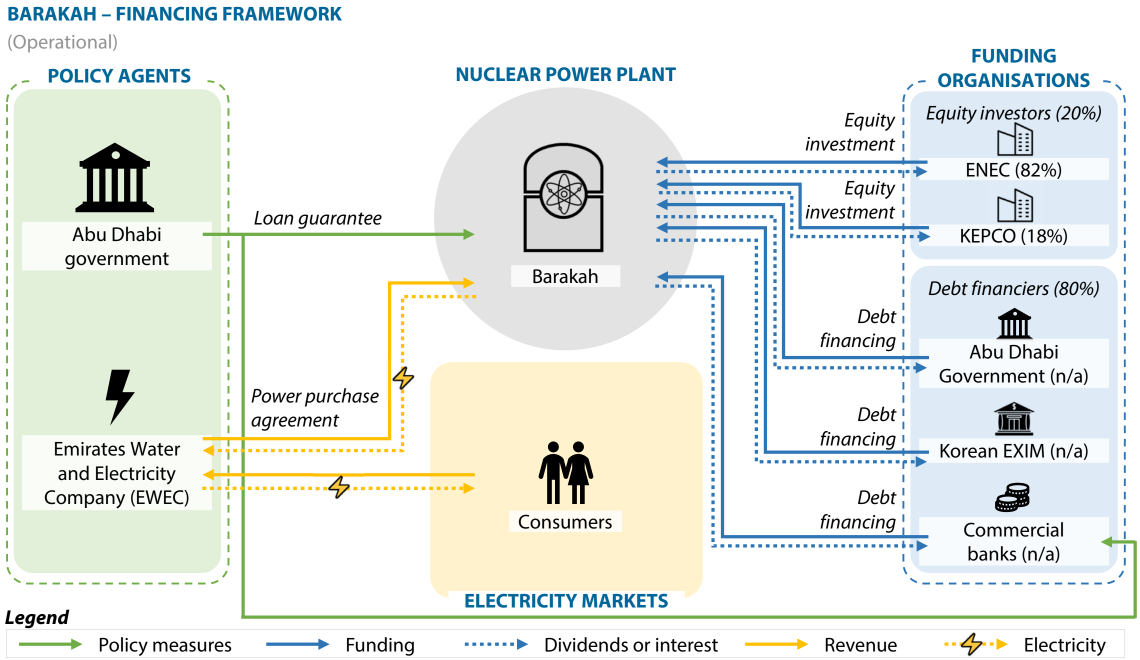
#### *Equity investment and debt financing*

Initially, ENEC and KEPCO invested a total amount of USD 4.7 billion into Barakah One Company.

At financial close in 2016, Barakah One Company had committed senior loan facilities totalling USD 19.6 billion. The Government of Abu Dhabi provided most of the committed debt facilities, with USD 16.2 billion in direct loans from the Department of Finance of Abu Dhabi, (accounting for 66% of the total funding at the time). The senior loan facilities have the benefit of completion support from ENEC and KEPCO and an early operating period financial guarantee from ENEC. The Department of Finance of Abu Dhabi also provided loan guarantees in respect of ENEC's payment obligation under the completion support and/or early operating period financial guarantee.

At financial close, the Export-Import Bank of Korea (Korean EXIM) provided a financial package of USD 2.5 billion in financial support. These Korean EXIM facilities were refinanced and fully repaid in 2023 with a commercial loan from First Abu Dhabi Bank (FAB) and Abu Dhabi Commercial Bank (ADCB). Additionally, there was a commercial debt facility from FAB, HSBC and Standard Chartered Bank at the time of financial close.

Figure 2.8: **Financing framework for the Barakah project**




## *Risk allocation*

The Barakah nuclear power plant was developed in a regulated electricity market. This resulted in a significant portion of the project risk being assumed by the UAE government. The State demonstrated strong support for the development of the project, providing political, financial, and commercial tools to ensure its success. However, a considerable amount of construction risk fell on the contractor and its suppliers, while operational risks are shared between the co-owners, ENEC and KEPCO.

- **Political and regulatory risks**: Political and regulatory risks for nuclear power plants are allocated to the UAE government, which is fully backing the project from a financial standpoint. The UAE government indirectly holds a majority stake in Barakah One Company, through ADQ (Abu Dhabi sovereign wealth fund) and ENEC, and has provided significant support for the project, including loan guarantees. These measures were designed to help mitigate the relevant risks to other stakeholders.
- **Construction risks**: The construction risks of the Barakah nuclear power plant were primarily borne by the construction consortium led by KEPCO, which included other Korean corporations such as Samsung C&T Corporation (Samsung), Hyundai Engineering and Construction (Hyundai) and Doosan Heavy Industries and Construction (Doosan). Samsung and Hyundai participated in the project through an EPC joint venture with an ownership of 45% and 55%, respectively. Doosan provided the Nuclear Steam Supply System (NSSS) and other major components, and Westinghouse offered technical assistance and licensing. While the details of the construction contract are publicly unavailable, it is assumed that the main contractors and the supply chain also partially shared the risks pertaining to the construction of the plant (IAEA, 2014).

  To mitigate some risks related to construction, KEPCO prepared hedging arrangements against inflation and currency volatility. ENEC and KEPCO agreed on a fixed price arrangement in their initial contract in 2009, but the pricing escalation clause was included to ensure compensation and protect KEPCO from cost increases from inflation. Additionally, KEPCO hedged currency risk associated with construction and agreed on a dual currency payment, with ENEC making payments partially in US dollars (85%) and partially in Korean Won (15%) (KEPCO, 2010).

- **Operational risks**: Unlike a conventional build-own-operate (BOO) model, the Barakah plant is co-owned and co-operated by its developer (ENEC) and lead contractor (KEPCO). As owners of the Barakah plant, both entities are involved in the operations of the power units. In addition, KEPCO and several of its subsidiaries have been appointed for the fuel supply, initial loading, operations support and maintenance services among other operational tasks (KEPCO, 2021).

  Nawah is the holder of the official operating licence of Barakah granted by FANR. The operating costs, however, are not borne by Nawah. Instead, the relevant costs are covered by Barakah One as stipulated in the Plant Services Agreement (PSA). Additionally, under the 60-year PPA with the state-owned EWEC, Barakah One Company can seek reimbursement for its O&M and fuel costs throughout the operating period, subject to periodic updates every five years (IAEA, 2018). This arrangement implies that the shareholders of Barakah One Company are only exposed to a limited risk should operating costs exceed the cost target.

- **Electricity market risks**: Barakah One Company assumes the responsibility of all commercial activities of Barakah. Similarly to the operational risks, much of the exposure to Barakah One Company is reduced through the PPA. The long-term PPA contracted for the entire capacity of Barakah mitigates the electricity market risk exposure of Barakah One Company. Instead, the risks are absorbed by EWEC, which is owned by the government.

- **Decommissioning and waste management risks**: The UAE government is in the process of finalising its strategy for the management of nuclear waste. However, the Barakah plant has been designed with an on-site spent fuel pool that will allow for storage for 20 to 30 years. The government plans to finalise and implement its long-term storage policy over this period of time. In the meantime, ENEC will be responsible for the safe storage of the spent fuel in accordance with national and international laws and regulations (ENEC, n.d.).

Figure 2.9: **Allocation of key project risks for the Barakah project**

| | | Political and regulatory | Construction | Operational | Electricity market | Decommissioning and waste management |
|---|---|---|---|---|---|---|
| **Operator** | Nawah Energy (ENEC, KEPCO) | No exposure | No exposure | No exposure | No exposure | No exposure |
| **EPC/vendor** | KEPCO Consortium | No exposure | High | No exposure | No exposure | No exposure |
| **Equity providers** | ENEC, KEPCO | Moderate | Moderate | Moderate | No exposure | No exposure |
| **Debt providers** | UAE government, commercial banks | No exposure | No exposure | No exposure | No exposure | No exposure |
| **Government** | UAE government | High | Low | High | High | High |
| **Consumers** | - | No exposure | No exposure | No exposure | No exposure | No exposure |

*Legend: Level of risk exposure* High | Moderate | Low | No exposure | Not applicable

### Role of government

The government of the UAE played a prominent role in the development of Barakah.

*Political support*

The UAE signed up to multiple treaties, protocols and conventions above and beyond those required to ensure that a transparent, responsible approach was demonstrated on the global stage. The UAE established a favourable environment for the project by providing a platform for constructive dialogue and fostering a welcoming political atmosphere for nuclear energy before the official commencement of the project. The governmental support was also accompanied by regulatory support with the rapid creation of FANR as an independent nuclear safety authority.

*Financial and commercial instruments*

The government assumed a significant portion of risks, providing financial and commercial tools to guarantee the success of the Barakah plant. Through ENEC, the government holds a majority stake in the power plant and has additionally funded the project through debt financing and loan guarantees. EWEC, another wholly government-owned entity, has entered into a PPA for the entire capacity of Barakah, securing a fixed price and eliminating market risks.

*Workforce development*

The government is approaching the Barakah project as a stepping stone for the long-term success of its national nuclear energy programme. The government has put an emphasis on the long-term transmission and localisation of human capabilities, working with KEPCO and other providers to ensure knowledge transfer and training of UAE Nationals to support sustainable Barakah plant operations. For the near-term need for qualified engineers, university programmes were established with the United States and Korea alongside state-funded scholarships (IAEA, 2019). The UAE now has multiple universities offering academic courses in nuclear engineering.

## Akkuyu project

### *Background*

The Akkuyu nuclear power plant (Akkuyu) is the first nuclear power generation plant to be built in Türkiye. The Turkish government had intentions to build a nuclear power plant since the 1960s, but the initiative had been delayed for various financial and political reasons. In 2010, Russia and Türkiye signed an intergovernmental agreement (IGA) on co-operation in relation to the construction and operation of a nuclear power plant at the Akkuyu site in the Republic of Türkiye.

The Akkuyu nuclear power plant consists of four VVER-1200 reactors totalling 4 800 MWe of installed capacity. Once in operation, the plant is expected to provide 10% of the Turkish electricity demand. The Akkuyu VVER-1200 reactors will be based on the Novovoronezh Nuclear Power Plant-2 reactor in Russia. Akkuyu will be the first nuclear new build project based on the build-own-operate (BOO) model that is otherwise widely used for a range of non-nuclear infrastructure projects (Akkuyu, n.d.).

In accordance with the IGA, the project company shall put the first unit into commercial operation within seven years from the date of issuance of all documents, permits, licences, consents and approvals necessary to start the construction and subsequent units, with one-year intervals consecutively. According to the IGA, the first unit of Akkuyu Nuclear Power Plant is planned to be commissioned in 2025.

### *Timeline*

The timeline for Akkuyu includes:

- **2010**: The Russian and Turkish governments signed an IGA to jointly build a nuclear plant and the project company, Akkuyu Nuclear Joint Stock Company (Akkuyu Nuclear JSC), was established.
- **2014**: The Ministry of Environment and Urbanization of Türkiye approved the Environmental Impact Assessment report for the Akkuyu project.
- **2017**: The Energy Market Regulatory Authority of Türkiye issued a 49-year electricity generation licence to Akkuyu and the Turkish Atomic Energy Authority authorised a limited work permit.
- **2018**: Akkuyu Nuclear JSC granted the main construction licence for unit 1 and the “first concrete” was poured into the foundation of unit 1, marking the official start of construction.
- **2019**: Akkuyu Nuclear JSC was issued the main construction licence for unit 2 by the Turkish Nuclear Regulatory Authority.
- **2020**: Akkuyu Nuclear JSC was issued the main construction licence for unit 3 by the Turkish Nuclear Regulatory Authority and the “first concrete” was poured into the foundation of unit 2.
- **2021**: Akkuyu Nuclear JSC was issued the main construction licence for unit 4 by the Turkish Nuclear Regulatory Authority and the “first concrete” was poured into the foundation of unit 3.
- **2022**: The “first concrete” was poured into the foundation of unit 4.
- **2024/2025**: Commissioning of Akkuyu unit 1 is expected, according to the IGA.
- **2028**: All four nuclear reactors are expected to have been put into operation according to IGA.

### *Financing framework*

Currently the project company is fully owned by companies of Rosatom State Atomic Energy Corporation (Rosatom). Akkuyu Nuclear JSC operates as a 100% subsidiary of Rosatom group companies.

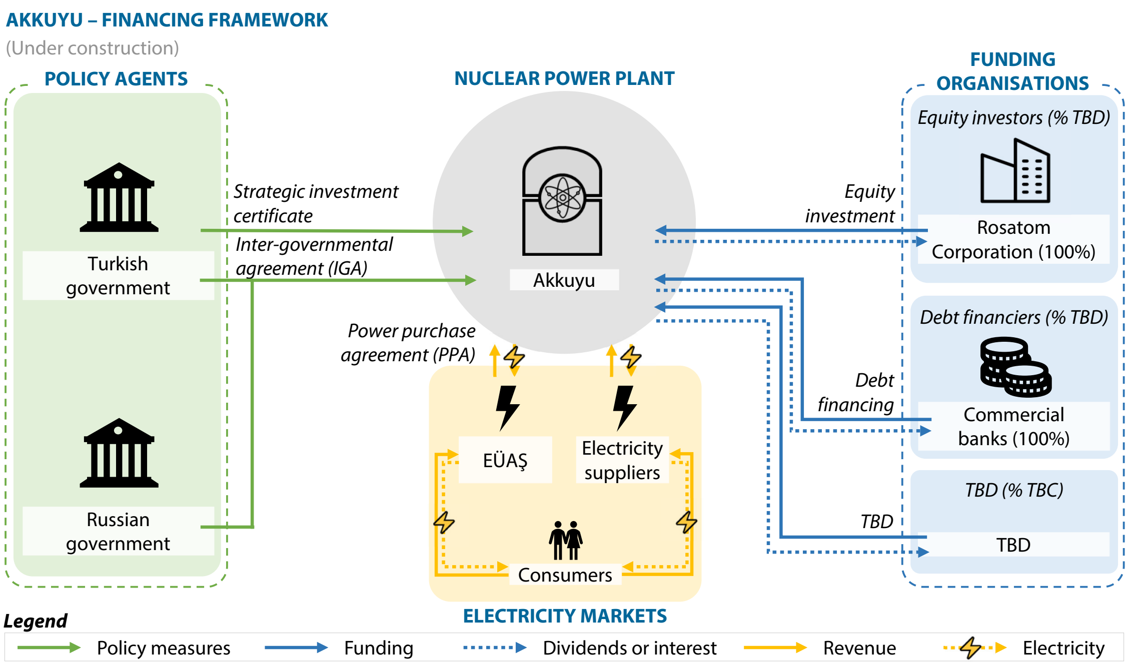
In accordance with the IGA, the Russian party shall retain a minimum 51% ownership in the project company at all times. This means that up to 49% of the shares in the project company are available for sale and can be sold to external investors, subject to mutual agreement between both parties. The project company, Akkuyu Nuclear JSC, is the investor, licensee and the owner of the nuclear power plant as well as its generated electricity (NEA, 2015).

The Akkuyu project has been financed by Rosatom as the sole equity investor in the project with loans from commercial banks. The details of those financial arrangements, as well as additional sources of funding to be secured, are not in the public domain.

#### *Strategic investment certificate*

A strategic investment certificate was issued to Akkuyu Nuclear JSC by the Turkish Ministry of Economy in 2018. The issuance of the certificate was based on the 2018 law "On amendments to the law on taxation, certain laws and regulations in the status of law". This preferential status provides tax reductions and exemptions as well as custom duty exemptions (Rosatom, 2018). In addition, Türkiye and Russia also stated that taxes and duties would be imposed in accordance with the IGA and the Avoidance of Double Taxation Agreement signed between the two countries (Akkuyu IGA, 2010).

Figure 2.10: **Financing framework for the Akkuyu project**

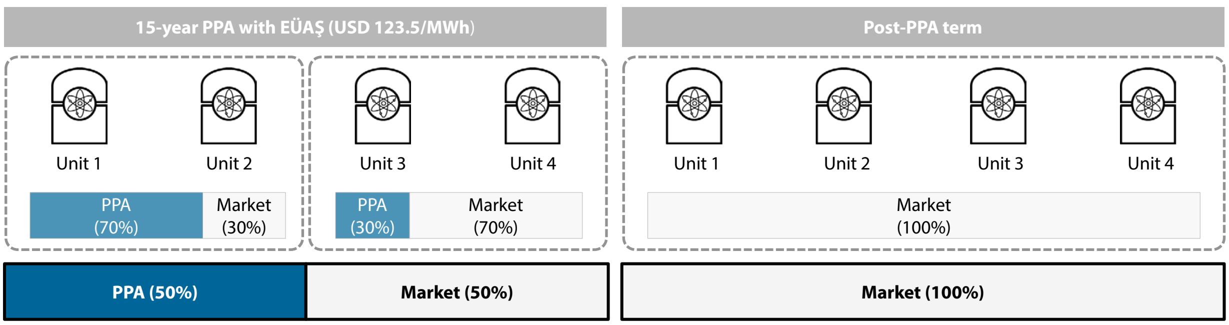



#### *Power purchase agreement*

Türkiye guaranteed electricity revenues through a power purchase agreement (PPA) with the Turkish Electricity Generation Company (EÜAŞ). EÜAŞ is a public state-owned generation company responsible for power plant operation. EÜAŞ will purchase 70% of the electricity produced in unit 1 and unit 2, and 30% of that from unit 3 and unit 4. The remaining generated electricity will be sold on the open market by Akkuyu Nuclear JSC or through a retail company. After the 15-year period, the full output will be sold on the market with 20% of profits channelled to the Turkish government.

The PPA price was signed at a weighted average price of USD 123.5/MWh. To ensure the payback of the project, annual variations of electricity price are possible, but capped at USD 153.3/MWh. The contractual arrangements and responsibilities in case of late/early commissioning of the power plant will also be reflected in the PPA price, but the details have not been disclosed (IAEA, 2018).

Figure 2.11: **Power purchase agreement scheme for the Akkuyu project**




### *Risk allocation*

The risks allocation for the Akkuyu project can be summarised as follows:

- **Political and regulatory risks**: All political and regulatory risks pertaining to the Akkuyu project will be mainly assumed by the Turkish government and partially by Akkuyu Nuclear JSC. As outlined in the IGA, as permitted by Turkish laws and regulations, the Turkish government has promised its full support in assuring timely and proper issuance of all necessary permits and licences. Moreover, the Akkuyu project has substantial political support from both the Turkish and Russian governments with clear strategies regarding nuclear energy.
- **Construction risks**: The Akkuyu project was signed under a build-own-operate model where the electricity purchasing agreement will not account for cost overruns. In this respect, the equity provider (Akkuyu Nuclear JSC) bears the main construction-related risks, with the EPC contractor assuming a moderate amount of the construction risk. As per the IGA, financial consequences pertaining to construction delays will be borne by responsible parties and Akkuyu Nuclear JSC will insure risks covering the project investment period. In the event of a failure, the Russian party must designate a competent successor to continue the construction (Akkuyu IGA, 2010).
- **Operational risks**: The responsibility of the operational risk lies with Akkuyu Nuclear JSC and its equity providers. Rosatom and its subsidiaries are held liable for providing all services related to operation, maintenance and fuel supply of the power plant. The operation costs will be covered through the future revenue generated by the Akkuyu plant through electricity sales (IAEA, 2019). As such, the operational costs will be deducted from prospective income before being channelled to the accounts of the equity providers.

  Additionally, Akkuyu Nuclear JSC is obligated to provide the agreed amount of electricity at the predetermined PPA price. In case of excess power production above obliged levels, the amount will be purchased in compliance with the provisions of the PPA. If production is less than what was stipulated, Akkuyu Nuclear JSC must procure the lacking volume from the market (Akkuyu IGA, 2010).

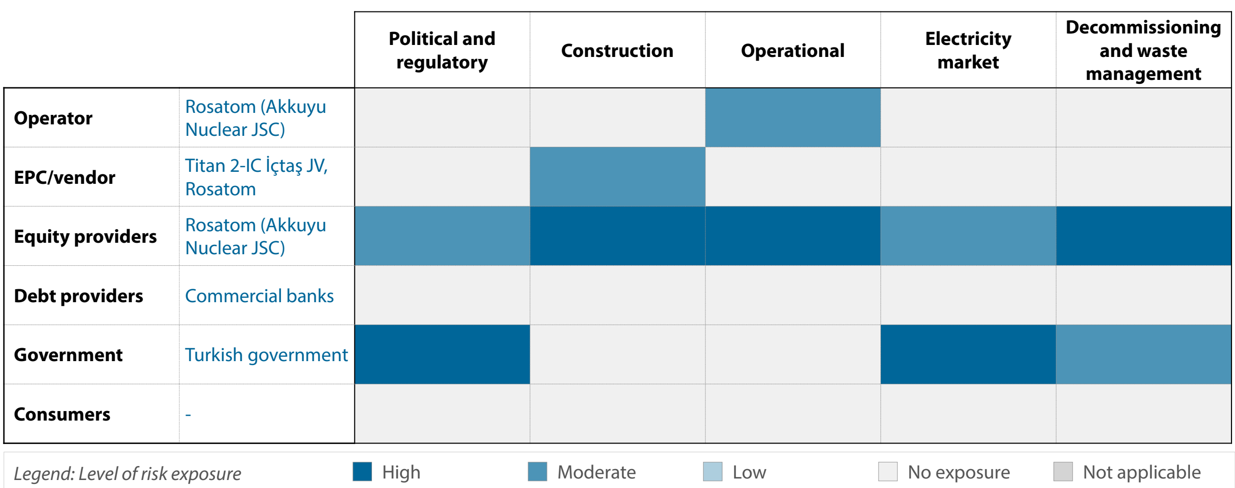
- **Electricity market risks**: EÜAŞ and Akkuyu Nuclear JSC will be sharing the revenue risk subject to market price volatility. Both parties will partially share exposure to the market through the PPA and adjustments to its fixed price. About 50% of the electricity to be generated at the Akkuyu nuclear power plant is secured by a PPA. EÜAŞ has not guaranteed the purchase of the entire capacity and therefore Akkuyu Nuclear JSC is partially exposed to the market. As per the time of the IGA signing in 2010, the agreed tariff rate was based on both the nuclear power plant cost estimate and the electricity price forecasts. The approach allowed the two parties to balance their risks.

  The PPA price of USD 123.5/MWh includes, among other, considerations for the unit price components of investment, fixed operating, variable operating and fuel cost. The IGA states that no escalation will be applied to these unit price components within the PPA period. If the changes in costs are incurred as a result of legislative or regulatory changes in Türkiye, the effects will be taken into account and reflected in the PPA (Akkuyu IGA, 2010).

  Furthermore, the denomination of the PPA price in US dollar exposes EÜAŞ to foreign exchange risk. Foreign exchange rate risk is particularly significant for emerging economies such as Türkiye (NEA, 2015). The Turkish economy has experienced considerable depreciation of its currency, Lira, against the US dollar in recent years, which further exacerbates the foreign exchange risk for EÜAŞ.

- **Decommissioning and waste management risks**: According to Turkish legislation, the owner of the power plant is required to make separate payments for decommissioning and waste management purposes. As such, according to the PPA signed with EÜAŞ, Akkuyu will pay a premium of USD 1.5/MWh for spent fuel and radioactive waste management and another premium of USD 1.5/MWh for decommissioning for the electricity purchased by EÜAŞ (Akkuyu IGA, 2010). The premiums to be paid for electricity to be sold to the market will be determined by the Akkuyu project Accounts Management Board and the premiums and guarantees will be updated annually.

Figure 2.12: **Allocation of key project risks for the Akkuyu project**



### *Role of government*

Türkiye has shown strong commitment as the host government and has provided various incentives for the development of the project. The Turkish government did not provide direct financing or sovereign guarantees but signed the IGA with Russia, which indirectly underpins the financing of the plant’s development. A series of indirect measures were also introduced such as the PPA, Strategic Investment Certificate and other policy support to maximise the involvement of the Turkish economy in the development of the Akkuyu project.

In parallel, Türkiye has stressed the importance of localisation and development of its local workforce as part of its collaboration with Russia. In the IGA, the two countries have agreed to facilitate technology transfers and the exchange of information and expertise, including training programmes. Turkish companies have also been involved in the supply chain in the construction of the power plant. Under the terms of the IGA, the two countries agreed for the project to rely on Turkish companies for the supply of commodities and services during construction (Akkuyu IGA, 2010). This emphasis on localisation and workforce development highlights Türkiye’s commitment in acquiring knowledge and capabilities related to civil nuclear energy, ultimately contributing to the country's domestic expertise in the field.

## Hinkley Point C project

### *Background*

Hinkley Point C (HPC) is the first new nuclear power plant to be built in the United Kingdom since Sizewell B was commissioned in 1995, and has been under construction since 2016. The two-unit power plant using an adapted EPR design based on EDF's Flamanville EPR design will be owned by Nuclear New Build Generation (NNBGenco HPC Ltd), a project company set up by EDF Energy (EDF). At the time of the final investment decision, the EDF Energy ownership share of NNBG was set at 66.5%, while that of China General Nuclear Power Group (CGN) was 33.5%. NNBGenco HPC Ltd will also be the plant operator. Each EPR reactor has a capacity of 1 600 MW and collectively will be able to produce 26 TWh of low-carbon electricity per year.

The current target date for unit 1 is 2029 and for unit 2 it is 2030. The project encountered several difficulties since the beginning of construction. In particular, the COVID-19 pandemic and global supply chain challenges that followed led to an additional delay of six months. This brought up costs net of interest during construction to GBP 23 billion (EDF, 2021). In January 2024, further cost rises have been announced, bringing the total to an estimated GBP 31-32 billion in 2015 monies (EDF, 2024).

### *Timeline*

The final investment decision in 2016 to build HPC was the outcome of about a decade of efforts to put in place a suitable set of policy measures to enable nuclear new build in the United Kingdom:

- **2006**: The 2006 Energy review led by the UK government supported investments by the private sector in new nuclear reactors and committed to address key policy and regulatory issues to enable these investments.
- **2011**: The planning permission for site preparation works at HPC was granted.
- **2012**: An assessment of the EPR reactor design was completed and the nuclear site licence was granted by the Office of Nuclear Regulation (ONR).
- **2013**: Government granted a consent order for HPC construction and operation.
- **2016**: A final investment decision was made by EDF (July) and the UK government (September).
- **2016**: Construction started for unit 1 (September).
- **2029-31**: Commissioning is expected for unit 1.
- **2030-32**: Commissioning is expected for unit 2.

### *Financing framework*

The financing framework for HPC (see Figure 2.13 below) is part of the United Kingdom's policy of building new nuclear plants to support long-term energy policy objectives in terms of decarbonisation, affordability and security of energy supply. The lack of industrial and human capabilities after 20 years without new nuclear construction in the United Kingdom was also an important part of the UK government's decision to provide a series of policy measures to support the project.

The HPC project is funded through the NNBG project company shareholders: EDF Energy and CGN. Both contribute to funding the project construction, including cost overruns, through equity and in proportion to their respective shareholder stakes. In addition, as a majority shareholder, EDF must consolidate the project in its balance sheet. While debt was not raised at the project level, the two shareholders of HPC raised debt that enabled the project at the level of the corporate balance sheets.

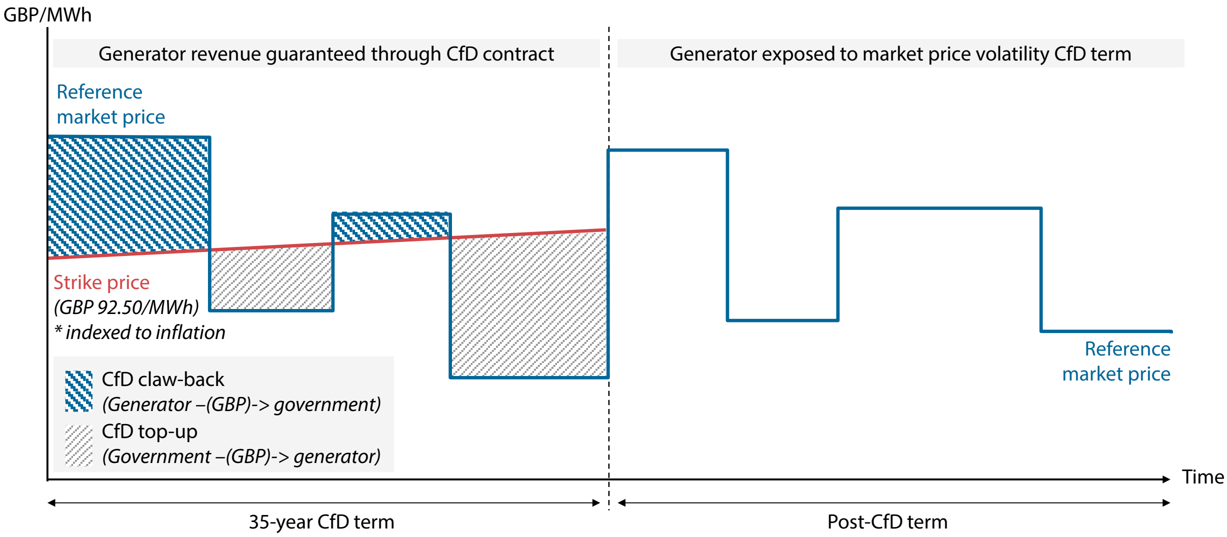
To enable this investment decision from EDF Energy and CGN, the UK government agreed on a series of policy measures that underpin the project financing framework.

*Contract for difference*

Contract for difference (CfD) mitigates electricity market risks by providing price certainty over the first 35 years of operation. For HPC, EDF and the UK government agreed on a strike price of GBP 92.50/MWh (indexed to inflation). The CfD is administered by a government-owned counterparty to generators, the Low Carbon Contracts Company (LCCC). When the strike price is below the reference market price, the LCCC charges a levy equal to the difference to NNBG, which is then passed on to the final consumers as a rebate on their electricity bill. Conversely, if the strike price is above the reference market price, a levy is charged on consumers to cover the difference, which is then paid to NNBG. In addition to being indexed to inflation, a clause of equity gain share is included in the contract: if NNBG's internal rate of return is higher than 9%, additional returns from NNBG's shareholders are shared with consumers.

It is worth noting that similar contracts have been supporting renewable energy projects in the United Kingdom, with the only major difference being the duration of this contract due to the difference of asset lifetime (60 years for nuclear vs. about 30 years for wind and solar PV).

Figure 2.13: **Hinkley Point C contract for difference model**




*Secretary of State Investor Agreement*

The Secretary of State Investor Agreement (SoSIA) guarantees compensation from the UK government to NNBG in case of a significant change in energy policy that leads to the HPC project being shut down.

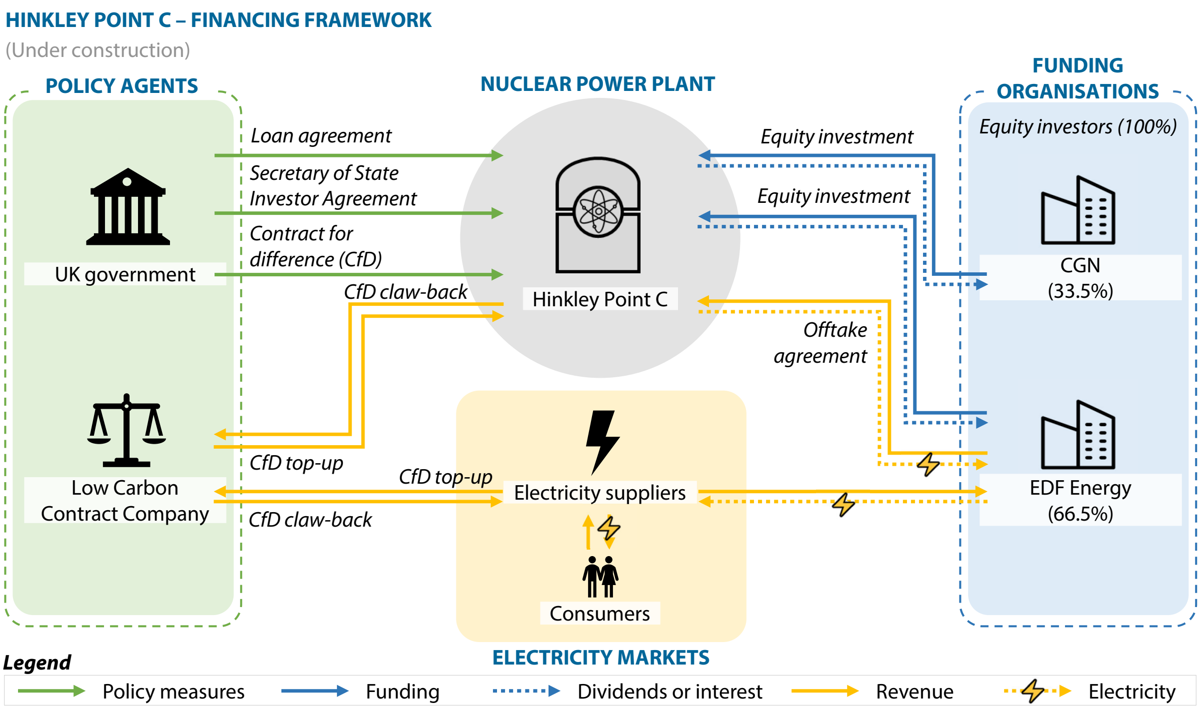
*Loan guarantee*

The UK Treasury offered an initial guarantee of up to GBP 2 billion to enable NNBG to issue bonds to finance construction. The debt guarantee is subject to a number of conditions that NNBG would have to meet and includes an additional level of debt guarantee up to GBP 13.1 billion. EDF has stated that it does not expect NNBG to make use of this guarantee.

*Funded Decommissioning Programme*

Last but not least, like other nuclear new build projects in the United Kingdom, HPC includes a Funded Decommissioning Programme which requires NNBG to set aside funds to pay for handling waste and decommissioning during operation. These final costs have been estimated at GBP 7.3 billion using a conservative methodology. The arrangements between the UK government and NNBG include a cap on some of the risks associated with the back end of the nuclear fuel cycle, for instance regarding the cost of a deep geological repository for high-level wastes.

Figure 2.14: **Financing framework for the Hinkley Point C project**



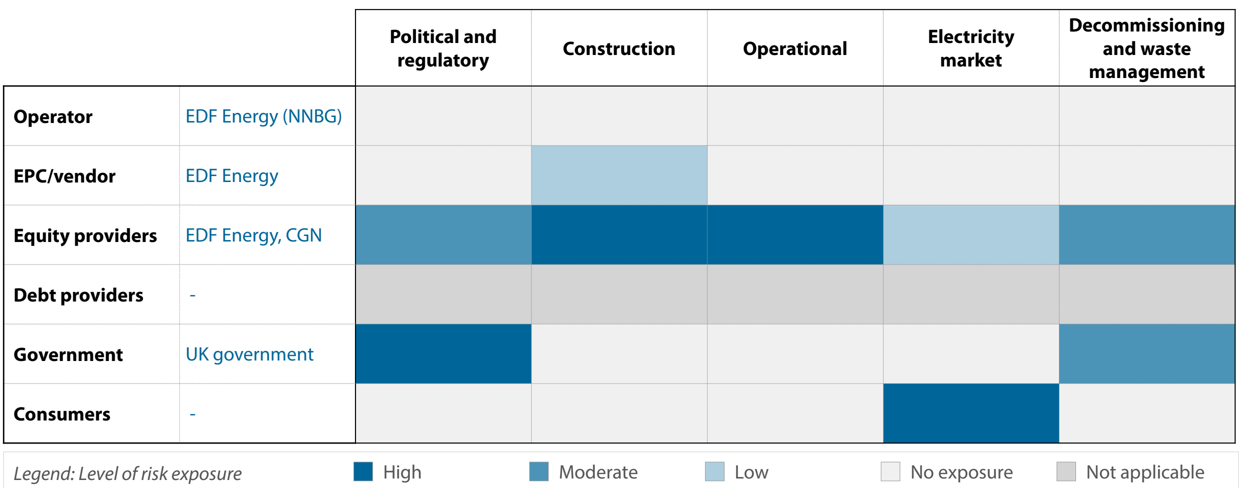

## *Risk allocation*

The set of policy support measures underpinning the financing of HPC are central to the allocation of key project risks between investors, the government and consumers.

- **Political and regulatory risks**: The Secretary of State Investor Agreement (SSIA) specifically ensures that political risks are allocated with the UK government. In particular, the UK government assumes the risks related to changes in policy that would lead to the project being either cancelled before commissioning or shut down prematurely during operation. This does not cover all types of political risks and does not include regulatory risks, meaning that EDF and CGN – as current co-investors in the project – maintain some risk exposure.
- **Construction risks**: The financing framework directs all the construction risks of the HPC project to its equity investors, EDF and CGN. This includes cost overruns and delays and completion. The risk of cost overruns and delays can be partly mitigated through contractual approaches with the nuclear supply chain mobilised during construction. However, EDF and CGN remain fully exposed to completion risk, unless the latter is due to a change in policy.

- **Operational risks**: The contract for difference means that the NNBG remains largely exposed to operational risks as the strike price only applies to the energy generated by the plant.
- **Electricity market risks**: The central role of the contract for difference is to ensure that the project company is not exposed to electricity market price risk. Those risks are essentially carried forward by consumers as the LCCC only acts as a counterparty and will transfer any difference between the strike price and the reference market price to consumers through either a rebate or a levy on electricity bills. As the contract for difference not only covers electricity market price risks but also represents an offtake agreement that would guarantee a volume of electricity to be contracted, HPC's shareholders retain a limited exposure to market risks related to offtake of the electricity generated.
- **Decommissioning and waste management risks**: The Funded Decommissioning Programme takes a conservative approach in that some of the risks are already priced into the fee structure. Nevertheless, EDF and CGN remain exposed to some of the risks and the government is responsible for some residual risks, for instance with a cap on the cost of a deep geological repository.

Figure 2.15: **Allocation of key project risks for the Hinkley Point C project**




This allocation of risks translates into a sizeable risk premium for HPC's shareholders because of the importance of construction risks in HPC, the first nuclear power plant being constructed in the United Kingdom over the last two decades and based on a reactor design whose first-of-a-kind projects were still under construction at the time of final investment decision. HPC investors' *ex-ante* weighted average cost of capital (WACC) was thus estimated at about 9%, significantly raising the price of electricity for consumers.

However, this cost of capital would have been much higher without electricity market risks being covered by consumers through the contract for difference and political risk being assumed by the government through the SSIA. The latter ensures that the NNBG's shareholders will earn a return on investment even if the plant is shut down before the planned end of operation due to a political decision.

The National Audit Office (NAO, 2017) conducted a study on alternative financing structures, including public investments. The HPC strike price would have been consequently reduced from GBP 92.5/MWh to about GBP 60/MWh with additional government financing support to reduce the WACC to 6%, in line with the social discount rates typically used to assess public investments. In particular, the National Audit Office analysis stressed that the time and cost overruns should be significant before consumers' additional cost equals the ones under the CfD model.

The project initially assumed a WACC of 9.2%. However, the final (*ex-post*) return on investment will be lower due to time and cost overruns.

### Role of government

The role of the UK government is focused on providing a level playing field to enable investment decisions from the private sector. The UK government refrained from taking additional risks related to construction (delays, costs overruns and completion), for instance through an equity stake in the project or additional regulatory measures.

The package of policy support measures from the UK government is justified by the declared intent to correct market failures in addressing residual carbon externalities, a lack of energy diversity and security of supply, insufficient incentives to invest in and develop immature technologies as well as financial market constraints (UK gov., 2017).

This position was further supported with a detailed value for money assessment that demonstrated that the CfD package offered a fair return to investors and would deliver net social benefits in the long term in a range of scenarios (UK gov., 2017).

## Sizewell C project

### *Background*

The Sizewell C project aims to build two 1 600 MW EPR reactors in Suffolk, United Kingdom. The project was proposed by EDF Energy and is envisaged as a replica of HPC. The project received its development consent order in 2022 and is awaiting a final investment decision. The UK government had the objective of reaching the point of final investment decision before the end of the 2019 Parliament. This was not achieved before the calling of a General Election in May 2024. Both leading UK political parties reference the importance of the project to their respective energy policy agendas in their manifestos.

The Sizewell C project will replicate much of HPC in terms of the detailed design, safety case and supply chain. It is expected to benefit from significant return of experience from HPC, which would reduce costs and construction risks. Being a Nth-of-a-kind (NOAK) project in the United Kingdom, Sizewell C was able to improve its risk profile, enabling the project to explore alternative financing options. In operation, learnings from other EPRs (including HPC) will also be expected to benefit operating performance.

### *Timeline*

The timeline for Sizewell C includes:

- **2006**: The 2006 Energy Review led by the UK government supported investments by the private sector in new nuclear reactors and committed to address key policy and regulatory issues to enable the investments.
- **2012**: The Generic Design Approval for the EPR reactor design was provided by the ONR.
- **2012**: EDF initiated a first community consultation for Sizewell C.
- **2020**: EDF submitted a government consent order as well as a licence application to the ONR to build and operate Sizewell C.
- **2022**: A Development Consent Order (approval of a key planning application) was issued by the UK government.
- **2022**: The UK parliament passed the Nuclear Energy (Financing) Act, which introduced the possibility of applying the RAB financing model to nuclear energy generation projects.
- **2022**: The UK government announced that it will invest GBP 679 million in the Sizewell C project, becoming a 50% shareholder with EDF during the development phase of the project.
- **2023**: The UK government made a further GBP 511 million investment in the project available. In September 2023, the UK government and Sizewell C Ltd launched an equity raise process – backed by the RAB model – to seek investment from further potential shareholders.
- **2024**: The UK government made a further GBP 1.3 billion of investment available, consolidating its position as the project's majority shareholder. Sizewell C Ltd triggered the project's development consent order, received the project's Nuclear Site Licence and confirmed purchase of the main construction site. The UK government consulted on modifications to the Sizewell C project licence and submitted a subsidy assessment to provide support to the project at the point of final investment decision.

### *Financing framework*

The Sizewell C project is still under discussion but the UK government has issued consultations on modifications to the Sizewell C economic licence and on the methodology for calculating specific elements of the licence.

The UK government has also submitted an assessment of subsidy that it would provide to the project at the point of any final investment decision. This is proposed to cover:

i. **An allowed revenue**: Through nuclear RAB funding, a revenue mechanism for investors to achieve a return on their investment during the construction, commissioning and the operational periods, plus recovery of the operating expenses of the plant such as fuel and maintenance.

ii. **A government support package (GSP)**: The UK government provision of support intended to cover against specific high-impact, low-probability risks that private investors would not be able or willing to finance themselves.

iii. **Government debt and equity finance**: The UK government will contribute to the project financing directly through debt and equity finance.

*Regulated asset base model and government support package*

In 2022, the UK parliament passed the Nuclear Energy (Financing) Bill, which provides the legal basis for applying a new financing framework to new nuclear power plants by introducing the use of the regulated asset base (RAB) model for nuclear projects. The RAB model has been widely used in other infrastructure projects in the United Kingdom, including energy networks, water companies, airports and in recent years the Thames Tideway Tunnel (TTT) greenfield construction project. Some variations of the RAB model have also been widely used for infrastructure projects in other OECD and NEA countries, for instance in Europe for energy transmission and distribution grid assets.

In practice, the RAB model is expected to work similarly to the CfD model in terms of revenue collection and payment (BEIS, 2022). This model empowers the Low Carbon Contracts Company (LCCC) to levy charges on suppliers to provide revenues for investors, including during construction. The allowed revenue is then passed on to final consumers by the electricity suppliers. The level of the levy charges is to be calculated by the Office for Electricity and Gas Markets (Ofgem), in line with the terms of the licence. Ofgem will publish economic guidance to demonstrate how they will go about calculating the revenue.

The RAB model will cover both the construction and operational phases:

- **Construction phase**: One feature of the RAB model envisaged for Sizewell C is that the project will be allowed to collect revenues from electricity consumers already during the construction phase. Revenue collected during construction would be primarily calculated based on the costs of servicing the financing costs during construction and the cumulative capital spent on the construction of the project.
- **Operational phase**: After commissioning of the nuclear power plant, the allowed revenues will also include the recovery of construction costs as well as operational costs. A difference payment mechanism similar to a CfD will be applied to take account of revenues from market sales and allowed revenues under the RAB. Under the licence, the project is obliged to maximise commercial revenues to minimise the size of the levy.

A key feature of the RAB is the creation of a regulated economic environment to allocate construction, operating and financing risks between investors, consumers and governments.

In the United Kingdom, the proposal may include a possible cap on the level of construction overruns private investors are obliged to finance. Figure 2.16 describes how the RAB model will address construction cost risks. The general approach can be summarised in three parts described below and illustrated in Figure 2.16:

1. **Baseline**: An asset base is built up progressively during construction and is proportional to the project costs, including the cost baseline and risk contingency. Both debt and equity contribute to the funding and will receive a return on investment, including during construction.

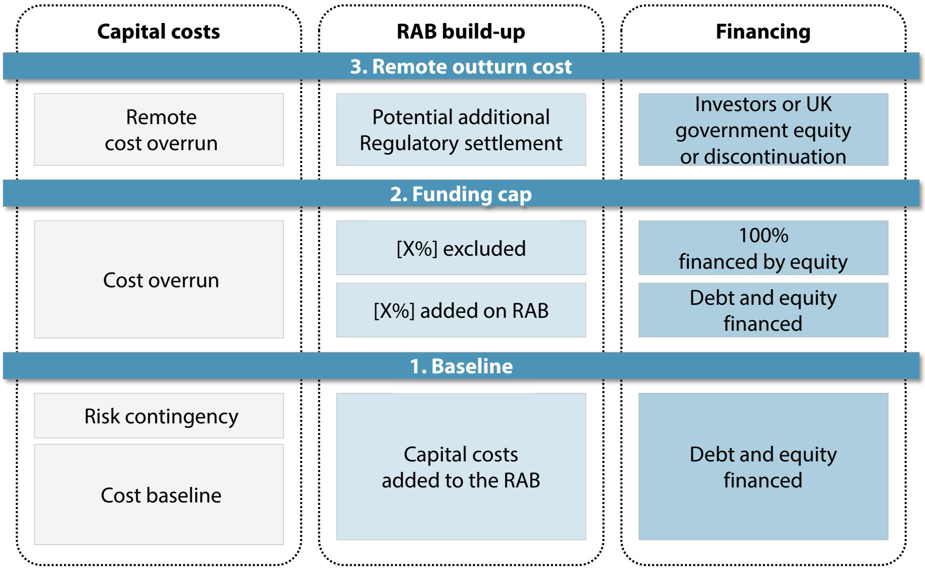
2. **Funding cap**: Cost overruns above the cost baseline and up to a funding cap will only partially be added onto the asset base. The percentage that will be allowed to be added to the RAB will be subject to a set of licence conditions under the oversight of the economic regulator, Ofgem. Cost overruns that are added to the asset base will be funded by both debt and equity investors, who will receive a rate of return commensurate to their investments. Cost overruns that are not added to the asset base will be funded by equity investors and will not generate any return.
3. **Remote outturn cost**: Additional cost overruns above the funding cap could be covered through a number of different options, such as additional investment by equity investors and adjusting the allowed revenue, as well as the UK government under an additional regulatory settlement (Government Support Package, GSP). The GSP would focus on specific low-probability but high-impact events in terms of costs overruns. In addition to construction cost risk, it is expected that there will be incentive mechanisms to penalise delays.

*Investment from the UK government*

In parallel to the RAB model and GSP model, additional important support is being provided by the UK government to the Sizewell C project via direct equity investment. In late 2022, the UK government announced an investment of GBP 679 million in the project, becoming a 50% shareholder alongside EDF. A further investment of GBP 170 million by the UK government was confirmed in July 2023 (UK gov., 2023), with a further GBP 341 million announced in August 2023. The government confirmed a further investment of GBP 1.3 billion in January 2024. This equity investment aims to support the project during its development phase, with the objective of subsequently attracting additional investors at financial close.

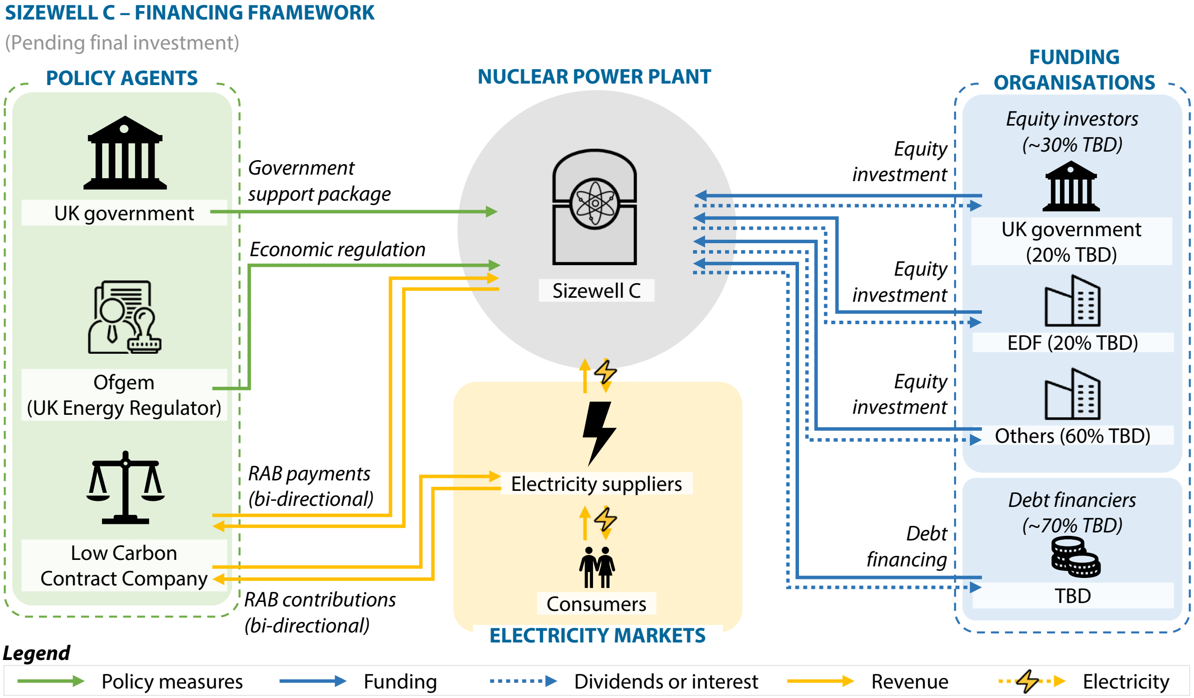
Based on this investment, the UK government has become the project's majority shareholder and has stated it will only accept private investment if it is likely to result in value for money to consumers and taxpayers.

Figure 2.16: **Regulated asset base (RAB) model and government support package (GSP) mechanisms**




Note: This is an illustration of how the risk sharing approach could work during the construction phase of a nuclear project. This is based on the approach used on Thames Tideway Tunnel.

Figure 2.17: **Expected financing framework for Sizewell C project**




### *Risk allocation*

The RAB model seeks to allocate risks in an efficient way to those best able to hold them. This yields a very different allocation of construction risks compared to the CfD model, leading in particular to these risks being shared explicitly between investors, consumers and the UK government.

By sharing risk in this way, these measures are expected to lead to a sizeable reduction of the expected risk premium compared to a project funded by the CfD model. The risk premium is defined as the additional return that is required to compensate for an increased level of risk above the risk-free rate. The UK government's impact assessment analysis for the Nuclear Energy (Financing) Act 2022 found using the RAB model could save between GBP 30 billion and GBP 80 billion when building and financing a generic large-scale nuclear power station (BEIS, 2021)[1].

In essence, this approach aims to maintain strong investor incentives by allocating some of the risk to the part best able to manage the risk before construction starts (*ex-ante*), while taking into account the ability of the different parties to absorb these risks after construction starts (*ex-post*).

- **Political and regulatory risks**: While the Nuclear Energy (Financing) Act does not explicitly refer to political and regulatory risks, it can be expected that those risks will be tackled in a similar fashion to HPC and will to some degree be allocated to the government through the GSP. This includes in particular the risks related to changes in policy that would lead to the project being either cancelled before commissioning or shut down prematurely during operation.

1. These figures are provided in 2021 prices and using 2021 as the base year.

- **Construction risks**: The RAB model leads to construction risks being allocated among investors, consumers and the government. The three-tier approach to allocating the risk of cost overruns means that equity investors and consumers will be the first exposed to these risks whereas under the CfD model, the risks of cost overruns and schedule delays are borne entirely by equity investors. Under the GSP, the UK government will only assume the residual "remote" risks, meaning its exposure is limited.

  Those risks are essentially carried forward by consumers as the LCCC only acts as a counterparty and will transfer any difference between the strike price and the reference market price to consumers through either a rebate or a levy on electricity bills. As the CfD only covers electricity market price risks but does represent an offtake agreement that would guarantee a volume of electricity to be contracted, HPC's shareholders retain a limited exposure to market risks related to offtake of the electricity generated.

- **Operational risks**: The RAB model means that the Sizewell C project company is expected to remain exposed to operational risks and be strongly incentivised to achieve strong operational performance through operational incentives within the allowed revenue set by the economic regulator, Ofgem.

- **Electricity market risks**: The RAB model is expected to work in a similar fashion to the CfD, meaning that Sizewell C's shareholders will not be exposed to electricity market price risks. Those risks will be shared with consumers, with the LCCC continuing to act as the counterparty between the project company and the electricity suppliers. However, the project will be obliged to maximise market revenues under the terms of the licence.

- **Decommissioning and waste management risks**: Under the Energy Act 2008, operators of new nuclear power plants are required to have a Funded Decommissioning Programme (FDP) approved by the UK government before nuclear-related construction can begin. The FDP is intended to ensure that operators have adequate financing arrangements in place to meet the full costs of decommissioning, waste management and disposal. Details of the FDP for Sizewell C are subject to ongoing development.

Figure 2.18: **Expected allocation of key project risks for the Sizewell C project**

| | | Political and regulatory | Construction | Operational | Electricity market | Decommissioning and waste management |
|---|---|---|---|---|---|---|
| **Operator** | Sizewell C | No exposure | No exposure | No exposure | No exposure | No exposure |
| **EPC/vendor** | Multiple contractors /EDF Energy | No exposure | Moderate | No exposure | No exposure | No exposure |
| **Equity providers** | EDF Energy, UK government, additional TBD | Low | Moderate | High | No exposure | Moderate |
| **Debt providers** | TBD | Low | Low | Low | No exposure | No exposure |
| **Government** | UK government | Moderate | Low | No exposure | No exposure | Low |
| **Consumers** | - | Moderate | Moderate | No exposure | High | Moderate |

*Legend: Level of risk exposure* High; Moderate; Low; No exposure; Not applicable

### *Role of government*

Compared to HPC, the UK government is taking a much wider role in the financing of Sizewell C. The UK government role in HPC was limited to addressing specific market failures to enable private investments in new nuclear construction. For Sizewell C, this role is expanding to include direct equity investment.

Under this new approach, the government is willing to set a new regulated economic model which shares some of the construction, operating and financing risks with consumers, and to channel residual risks to taxpayers. In parallel, a direct equity stake in the project has already been taken. This will translate in a much more active role for the UK government in the delivery of the project.

## Paks II project

### *Background*

The Paks II nuclear power plant, also known as Paks II, is a project being planned by Hungary to expand its existing nuclear power generating capacity. The four existing nuclear reactors built in the 1980s, supporting more than 50% of electricity production in Hungary, are set for retirement in the 2030s. The Hungarian government is preparing further lifetime extensions for existing operating units and exploring opportunities for new builds. To address the ageing power plants and meet the growing electricity consumption, they plan to construct new units 5 and 6, which will supply electricity to the country.

The two units will be adding 2 400 MWe in capacity and will be operated by Paks II Nuclear Power Plant Ltd., (formerly MVM Paks II Nuclear Power Plant Development Private Company Limited by Shares) (Paks II) (EC, 2017). According to the Hungarian Energy Minister, the Paks II plant is now expected to be completed in the beginning of the 2030s (WNN, 2023a).

In 2014, Russia and Hungary signed an intergovernmental agreement (IGA) for two VVER-1200 reactors to be procured from Rosatom State Atomic Energy Corporation (Rosatom) from Russia. Alongside the reactors, Hungary and Russia signed separate implementation agreements that specified collaboration in the areas of engineering procurement and construction (EPC), Operation and Maintenance (O&M) support and fuel supply (EC, 2017). The Hungarian Parliament adopted the bill regarding nuclear co-operation between the two nations in the same year (Paks, n.d.).

The European Commission (EC) approved Hungary's State Aid for Paks II in 2017 under condition that certain requirements are met (EC, 2017).

### *Timeline*

The timeline for Paks II includes:

- **2009**: The Hungarian Parliament approved a government decision-in-principle to build additional nuclear capacity, with Russian reactors the preferred option.
- **2012**: Magyar Villamos Művek (MVM) Paks II Ltd. was established as a stand-alone company for the preparation of the new nuclear build.
- **2014**: Hungary and Russia signed an intergovernmental agreement (IGA), a financing intergovernmental agreement (FIGA) and three implementation agreements.
- **2015**: The EC initiated an investigation into state aid provided for Paks II.
- **2016**: Paks II received the environmental licence, which became legally binding in 2017.
- **2017**: The Hungarian Atomic Energy Agency (HAEA) issued the site licence for Paks II and the EC approved the project's compliance with state aid regulations.
- **2019**: The engineering design was approved and construction of the first installation facilities began.
- **2020**: Paks II submitted its application for a construction licence to the HAEA to start the construction, production, acquisition and assembly works.
- **2021**: Approval was given to manufacture the two reactor pressure vessels.
- **2022**: The HAEA issued a licence for the construction of the two units at Paks II, construction permits for the unit 5 reactor building and the six buildings of the nuclear island, and manufacturing permits for the reactor pressure vessels and the core catchers.
- **2024**: First concrete is expected to be poured by the end of 2024

### *Financing framework*

The financing framework for the Paks II project is a standard example of a large-scale nuclear project with funding directly provided to the customer country by the vendor country under an IGA.

#### *Debt financing*

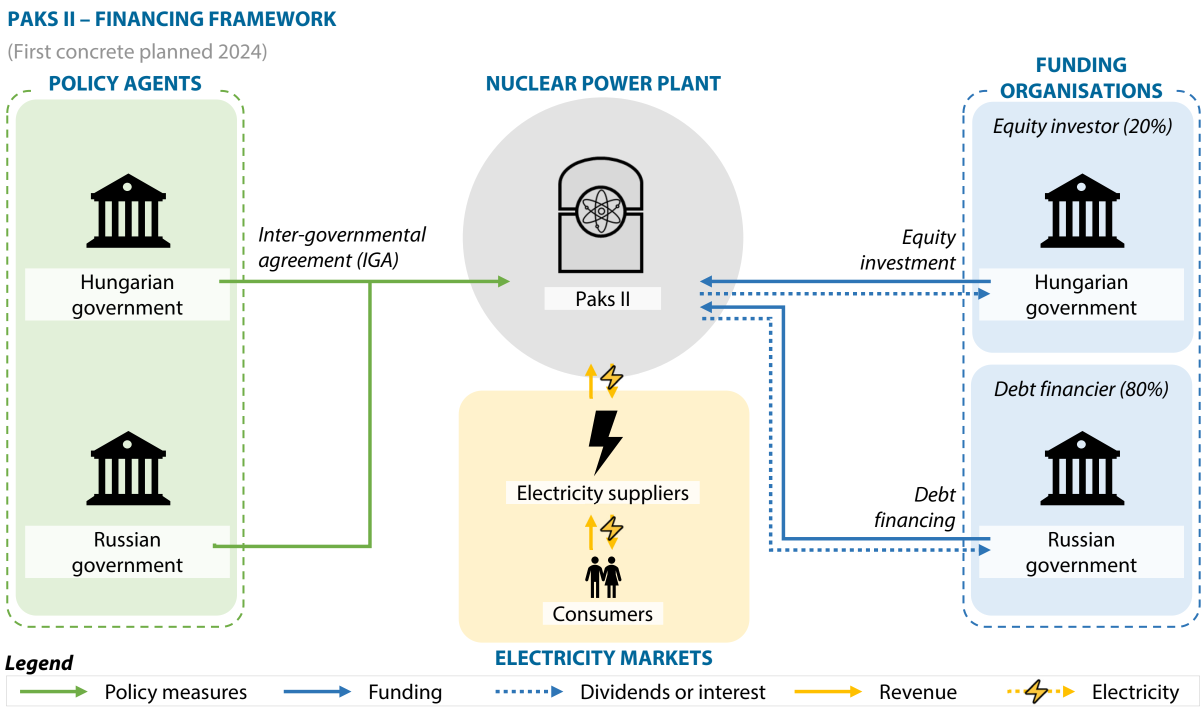
Russia is a leading exporter of reactors and offers attractive financing packages to prospective customer countries (CGEP, 2020). As such, Russia provided a credit facility of up to EUR 10 billion for the design, construction and commissioning of units 5 and 6 at Paks II following the signature of an IGA in 2014. This debt financing will cover 80% of the entire EPC contract value, which totals up to EUR 12.5 billion. The loan interest rate ranges between 3.95% and 4.95% and the loan was originally restricted to be used until 2025 by Hungary. The principal debt repayment was originally designed to start within 21 years following the commissioning of both units, but no later than 15 March 2026 (EC, 2017).

Following a delay to construction due to the approval process of the EC, the Hungarian government requested an extension to the loan period from the Russian Ministry of Finance in 2020. As a result, the loan terms were extended by five years. The loan use period was updated from 2025 to 2030, and the start of the repayment period from 2026 to 2031, respectively. The final maturity of the loan remained unchanged at 15 September 2046 (NEI, 2021).

#### *Equity investment*

The balance of EUR 2.5 billion of the project cost will be self-funded by the Hungarian government. Furthermore, Hungary has outlined that it does not intend to grant any further financial support to the Paks II project once the two units are constructed (EC, 2017).

Figure 2.19: **Financing framework for the Paks II project**



*Compliance with European Commission competition rules*

The EC concluded that the contractual and financing framework of the Hungarian government complied with EU rules and the resolution was passed (EC, 2017; Rosatom, 2017). The Hungarian government subsequently agreed to comply with the following three conditions:

i. the residual income from the operation of Paks II should not be invested for further capacity expansion;

ii. Paks II must be legally and structurally separated from the existing state-owned utility MVM; and

iii. the electricity generated will be sold in the open wholesale market to ensure market liquidity.

### *Risk allocation*

The risk allocation for the Paks II project can be summarised as follows:

- **Political and regulatory risks**: As the Paks II nuclear power plant is a government-driven project, further underpinned by an intergovernmental agreement with Russia, most of the risks pertaining to political factors will be absorbed by the Hungarian government. In addition to providing a favourable political ground for the Paks II project, the Hungarian government is also providing equity investment of 20%. Moreover, the government has been displaying its strong will to continue the project. In May 2023, the European Commission approved the latest amendments of the EPC and financial intergovernmental agreement. The Hungarian Foreign Minister highlighted the importance of nuclear power, that no energy security or green transition can be made without civil nuclear electricity generation (WNN, 2023b). The latest sanctions packages of the EU *(amending Regulation (EU) No 833/2014 concerning restrictive measures in view of Russia's actions destabilising the situation in Ukraine*) mention the project in several places as a way of derogation (EUR-Lex, 2023).

- **Construction risks**: Russia appointed the Joint Stock Company Nizhny Novgorod Engineering Company Atomenergoprojekt (JSC NIAEP) as the EPC contractor for the construction of the new Paks units. JSC NIAEP is the engineering division of Rosatom and has been renamed the ASE Joint Stock Engineering Company (ASE JSC) (Rosatom, 2016).

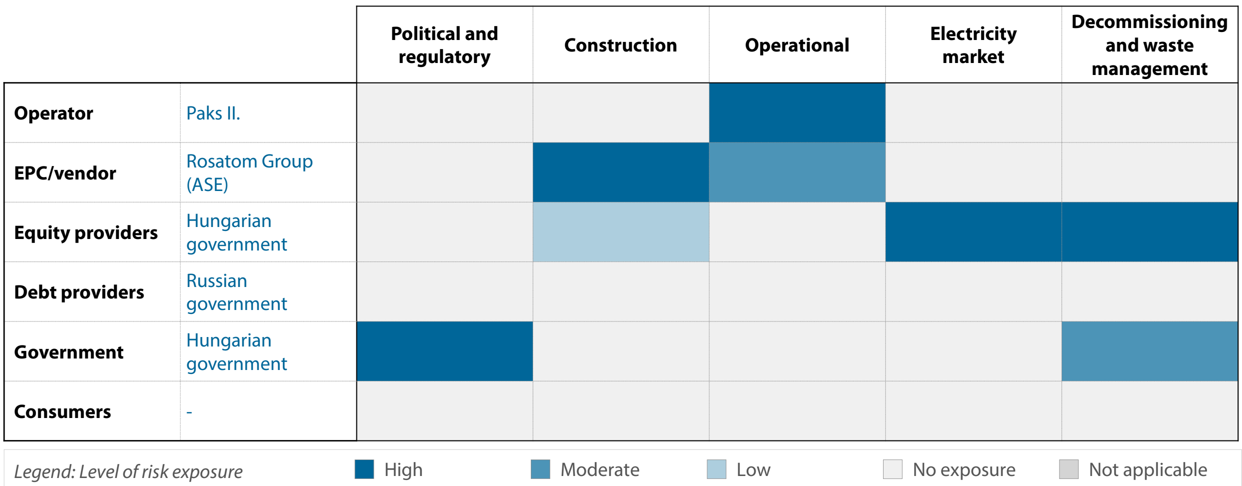
  The EPC contract has been signed under a fixed price turnkey scheme with a contract value of EUR 12.5 billion as defined under the IGA. The EPC contractor, ASE, will therefore be the main risk-taker for exposure pertaining to construction.

- **Operational risks**: Paks II has been appointed by the Hungarian government as the owner and operator of the 5$^{th}$ and 6$^{th}$ units (EC, 2017). The execution of operations is to be performed by Paks II, where Rusatom Service will support the operations and maintenance work (as outlined in the O&M support contract signed with Paks II). In the contract, an annual fixed fee basis is set for the work performed by the contractor. Furthermore, ASE (Rosatom Service) has agreed to provide a Performance Bank Guarantee and Parent Company Guarantee. The designated financial institute and ultimate parent company of ASE (Rosatom Service) will guarantee that the nuclear power plant meets its obligations under the operation and management contract (Paks II, 2014).

- **Electricity market risks**: The Hungarian government has not presented any power purchase agreement in its project development plant. The electricity generated by Paks II will be sold on the open market and to electricity consumers through power sale agreements following regular market practices. As a result, units 5 and 6 will operate under market conditions without any predetermined revenue or guaranteed pricing. The government expects that Paks II will function as a price-taker in the market as a baseload generator, similarly to the existing nuclear power plants in Europe (EC, 2017). The plant owner is therefore fully exposed to electricity market risks. As the Hungarian government is currently the sole shareholder in this company, it indirectly owns this project risk.

- **Decommissioning and waste management risks**: Risks pertaining to decommissioning activities and the management of nuclear waste will be shared between the government and the plant owner. The Hungarian government is responsible for temporary and final disposal of radioactive waste, spent fuel and decommissioning of equipment as underlined in the Act CXVI of 1996 on Atomic Energy. The end-cycle activities are funded through the Central Nuclear Financial Fund, which is financed by the owners (i.e. equity providers) of the operating nuclear plants, currently Paks I and later Paks I and Paks II together (MVM, 2022).

Figure 2.20: **Allocation of key project risks for the Paks II project**




### *Role of government*

The Hungarian government is actively involved in the development of the Paks II nuclear power plant. The government assumes the primary risk for the project for political, market and end-cycle risks. Through the equity investment of EUR 2.5 billion in the Paks II project, the government has supported 20% of the total financing.

In the initiation process, the Hungarian government has set favourable political and market conditions to support the construction of Paks II. It has provided legislative support for the development of units 5 and 6, ensuring a solid legal framework. Additionally, the Hungarian government has taken diplomatic initiatives to secure the necessary reactor technology and financing. By signing the IGA with Russia in 2014, Paks II has been able to establish a streamlined project process encompassing financing, EPC, O&M and fuel supply.

## Dukovany project

### *Background*

The Dukovany Nuclear Power Plant is located in the southeast of Czechia. Commissioned between 1985 and 1987, the plant operates four nuclear reactors for a total installed capacity of 2 040 MWe. In 2019, the Czech government gave approval for additional nuclear builds, as the country was expected to face an electricity deficit starting 2026 (ČEZ, 2020). Based on the government decision, the Ministry of Industry and Trade (MIT) instructed investors to launch the selection procedure for the new Dukovany unit in 2022 (WNN, 2022).

The project is expected to be completed by 2036 with an estimated budget of EUR 7.74 billion (EC, 2022). To implement the project at the Dukovany site, the Czech utility ČEZ established a subsidiary named "Elektrárna Dukovany II, a.s. (EDU II)". In November 2021, three vendors – EDF, Korea Hydro & Nuclear Power (KHNP), and Westinghouse – passed the security appraisal and were invited to submit bids. The initial bids were submitted in November 2022 and the updated bids were submitted in October 2023. In January 2024, the Czech government instructed EDU II to ask bidders EDF and KHNP to submit offers for the binding options for up to four new nuclear units (Dukovany 5 and 6 and Temelín 3 and 4). In July 2024, the Czech government announced the selection of KHNP as the preferred bidder. A final investment decision is expected in 2025.

ČEZ is currently majority-owned by the Czech government with a 70% equity stake.

### *Timeline*

The timeline for Dukovany 5 includes:

- **2015**: The "National Action Plan for the Development of Nuclear Energy" was approved by the government and "Elektrárna Dukovany II, a.s." was established.
- **2019**: The Czech government declared that it would provide ČEZ with loan guarantees to help secure financing and gave preliminary approval for at least one new nuclear power unit.
- **2020**: An application for two PWRs was submitted to the Czech nuclear regulator for sitting permit according to the Atomic Act, and issued in 2021.
- **2021**: EDU II submitted the documentation for the siting permit according to the civil construction law to the Třebíč Municipal Authority.
- **2022**: A tender was launched for a new nuclear power plant at Dukovany, with three candidates; the European Commission commenced its formal investigation for state aid rules.
- **2024**: European Commission approved, under EU state aid rules, the support measures for the construction and operation of Dukovany 5.
- **2024**: KHNP selected as preferred bidder.
- **2025**: The EPC contract for Dukovany 5 and potentially Dukovany 6 is expected to be signed. The options for Temelín 3 and Temelín 4 are to be exercised later.
- **2029**: First concrete is expected to be poured.
- **2036**: Connection to the grid is expected.

### *Financing framework*

The financing framework for the Dukovany 5 project is expected to include the following components:

*Debt financing through state loan*

The Czech government has confirmed that it will provide a state loan to support the construction cost of the new unit. Initially, the government had announced a state-funded loan to finance the project with approximately of 70% of the construction cost, with the remaining 30% to be financed by ČEZ (WNA, 2023). In 2021, it was decided that the state-loan financing (based on the Act on Measures for the Transition of the Czech Republic to a Low-Carbon Energy Sector and Amendment of Act No. 165/2021 Coll., On Promoted Energy Sources as amended) will be extended to the preparation stage after the selection of the EPC contractor. In the proposal submitted to the European Commission for the state aid investigations, the Czech government showed this extended support in the loan provision.

The state loan is estimated to be EUR 7.56 billion (at 2020 price levels) and will cover approximately 98% of the total construction cost. During construction, the Czech government will be charging 0% interest on the loan. Once the construction is complete, the interest rate will be based on the Czech state debt costs for the given year plus an additional 1 percentage point.

The estimated repayment period for the state loan is 30 years, starting after the operational permit for the plant is obtained, according to the Atomic Act, unless refinancing starts earlier. The State loan will be secured through the assets of EDU II, with no recourse or guarantee by ČEZ (EC, 2022).

*Equity investment*

The remaining equity investment of 2% of the construction cost translates to approximately EUR 180 million. This equity portion will be funded by ČEZ, the owner and operator of the Dukovany plants. It corresponds to the costs of the first stage of the project before selection of the EPC Supplier. An additional EUR 1.77 billion of equity investment may be committed contingent upon certain potential cost overruns. The details on financing regarding the cost overruns are subject to agreement between ČEZ and the government (EC, 2022).

*Power purchase agreement (PPA)*

The Czech authorities compared different support mechanisms including tax credits, capacity programmes, grants, the regulated asset base (RAB) model, contract for difference (CfD) and power purchase agreements (PPA). Under the EU State Aid case, the Czech government initially proposed a 60-year PPA to transfer the electricity market risk to the government. This approach was also envisaged to mitigate potential impacts on the functioning of the wholesale electricity markets as the market power of ČEZ on the wholesale electricity market would be reduced compared to a CfD. In its approval of the State Aid case, the European Commission requested that in the PPA a fixed value for the strike price be replaced by a remuneration formula akin to a two-way CfD. The European Commission expects that the introduction of a formula to PPA will provide additional incentives for plant operations to respond to market signals. The European Commission approved the PPA duration of 40 years.

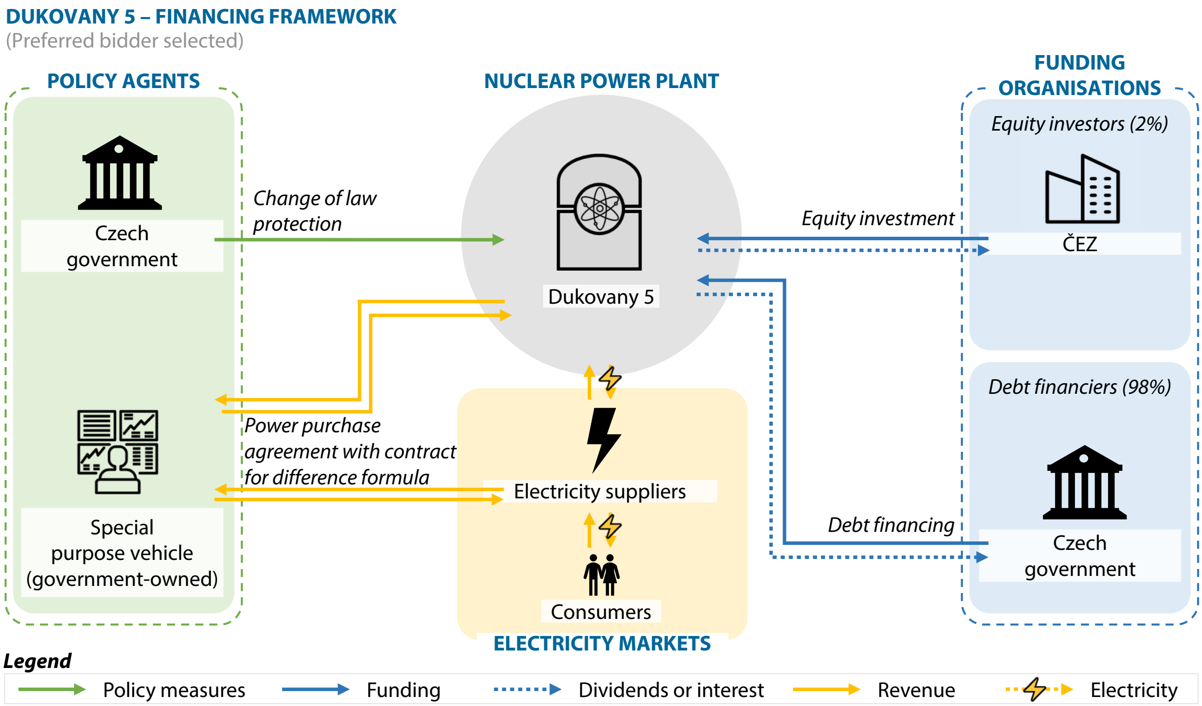
To avoid market concentration and remove the risk of the measure providing an advantage to certain electricity consumers, at least 70% of the power output will be sold on the wholesale market.

In addition, to address the risk of overcompensation, the European Commission asked Czechia to implement a claw-back mechanism to ensure that additional gains generated by the project will be shared with the Czech government.

*Investor protection mechanism against change of law or policy*

The government aims to extend legal certainty to shield the investor from potential adverse effects from modifications to legislation and taxation that may induce a higher cost of operations for the nuclear unit. ČEZ will benefit from a cost recovery protection against changes in the national agenda regarding the Dukovany unit 5 project. This includes changes in the national nuclear energy policy, failure to uphold the commitment to grant the policy support measures outlined above, or delays to the project due to the rejection of bids from prospective vendors. During the preparation and supplier selection stage, the purchase price for the sale of all shares to the State is fixed at EUR 0.19 billion (EC, 2022).

Figure 2.21: **Expected financing framework for the Dukovany 5 project**




### *Risk allocation*

As the project has not reached a final investment decision yet, several details are yet to be finalised. Nonetheless, the Czech government has already presented several mechanisms to mitigate the risks for potential investors.

- **Political and regulatory risks**: The Czech government has promised to assume a great portion of political and regulatory risks by demonstrating robust support for the development of a new nuclear power plant with political endorsement, financial facilities and PPA guarantees over 40 years. The State has also explicitly announced a share purchase guarantee mechanism to safeguard investors against unforeseeable events including legal and political changes. This protection will be viable for the entire investment period of the new Dukovany unit (EC, 2022).
- **Construction risks**: Although the negotiations for the EPC contract of Dukovany were still underway in August 2024, the Czech government has developed a risk allocation scheme in its State Aid plans submitted to the EC. Risks pertaining to construction will be shared between the project company (EDU II) and the Czech government. EDU II will bear the responsibility for any project disruptions pertaining to financial challenges and cost overruns, unless the issues are caused by a legitimate change.

  The Czech government, in turn, will be responsible for construction risks due to legal and regulatory factors. As the EPC contract negotiations are still ongoing, how much of the construction risk may be carried by the vendor has yet to be clarified (EC, 2022).

- **Operational risks**: EDU II, the subsidiary of ČEZ, will be operating the new Dukovany units. The state aid document has designated the operator to be responsible for any reduction in nuclear power plant availability due to operational problems. This includes any changes caused by operator errors, equipment malfunctions, or non-compliance with grid and safety regulations, resulting in an unexpected shutdown, except in cases where the cause is due to legal changes (EC, 2022).

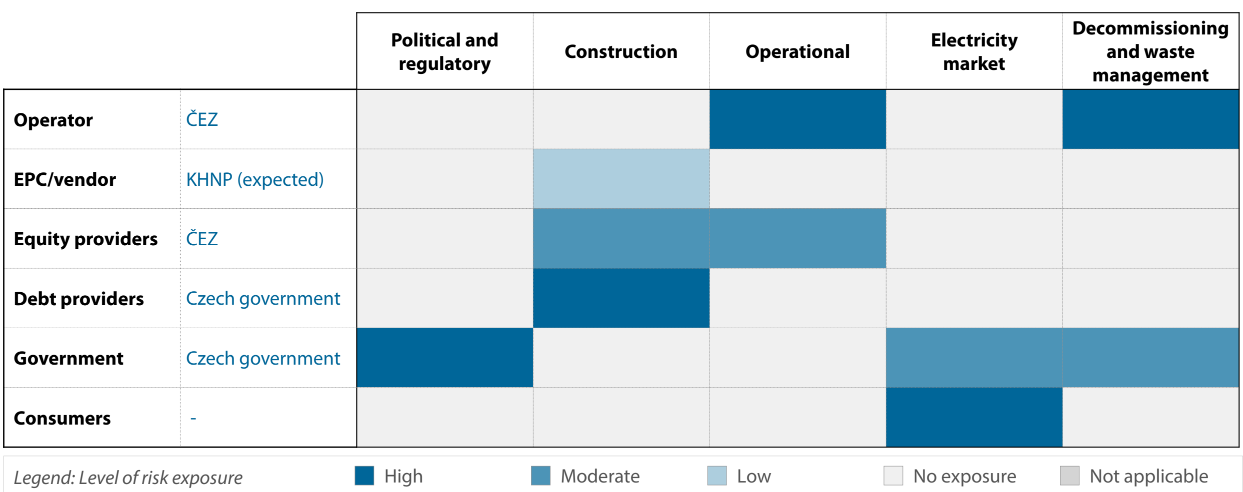
- **Electricity market risks**: Electricity market risks will be shared between the government and consumers through the CfD scheme. The Czech state is offering a PPA to EDU II, with a duration of 40 years. The electricity will be sold to a special purpose vehicle (SPV), a 100% state-owned entity holding an electricity trading licence. The SPV will then sell at least 70% of the electricity on the Prague Energy Exchange (PXE) or other exchanges.

  The CfD formula in the PPA offers stability to the investors, while the market risk will be shared between the State budget and consumers' electricity bills. If the wholesale market price of electricity exceeds the agreed strike price, it is expected that the surplus revenue will be directed towards reducing electricity prices for consumers. Conversely, if the market price of electricity falls below the strike price, it is expected that losses will be offset through financial compensation from the State and/or a levy paid by the end consumers (EC, 2022).

- **Decommissioning and waste management risks**: The government of Czechia sets the framework of the nuclear back end, but the relevant costs and operations will fall under the scope of the operator. In compliance with the EU's Radioactive Waste and Spent Fuel Management Directive, the strike price will reflect the operator's decommissioning costs, and relevant risks will be borne by the operator of the nuclear power plant. Used nuclear fuel, additionally, will be initially handled and stored by the operator until it is handed over to the State for permanent disposal.

  Thereafter, the Radioactive Waste Repository Authority (SÚRAO) is responsible for the long-term management of radioactive wastes, including spent fuel. SÚRAO carries out its activities with the financial support of a dedicated fund. This fund receives regular contributions from the nuclear operator, and the related liability of paying into the fund is reported as a separate item on the balance sheet of the operator. Furthermore, the Czech government has taken on the responsibility of outlining a precise timeline for selecting a final location for the repository. The final decision is expected to be made by the close of the 2030s (EC, 2022).

Figure 2.22: **Expected allocation of key project risks for the Dukovany 5 project**



### *Role of government*

The Czech government is taking an active role creating a favourable political environment towards the new unit of the Dukovany Nuclear Power Plant and projecting strong signals to investors regarding the project's viability. The state has promised three measures to support the project:

- a state loan;
- a power contract; and
- an investor protection mechanism against changes in law or policy during the investment period.

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# Chapter 3. Comparative analysis and key lessons learnt from the NEA nuclear financing case studies

The eight case studies in this report provide both a reference document to inform policy discussions and the basis for comparative analysis about the merits of different financing frameworks. This comparative analysis can be applied to a number of features of nuclear financing frameworks, including financing and revenue streams, approaches to risk allocation, as well as the respective roles of public and private parties. The present section provides a summary of these key findings, highlighting relevant lessons for future projects.

## Key findings on the sources of equity and debt financing

The projects analysed in the case studies were characterised by different financing schemes, with varying debt-to-equity ratios and degrees of governmental support. These variations can be attributed to the specific characteristics of each project, including national strategic priorities, financing availability and in particular financing underwritten by the government, capital market structures, as well as the industrial context, including design and supply chain maturity.

These specific national and industry contexts are reflected in the ways each project has made decisions for the sources of financing. For instance, in the cases of Barakah and Dukovany 5, substantial government financing is leveraged to ensure energy policy priorities in terms of security of supply and decarbonisation are met. On the other hand, the Olkiluoto and Vogtle 3 and 4 projects were initiated by market-driven considerations, where private investors played a key role in investment decisions.

Table 3.1: **Sources of financing of nuclear new builds**

| | Debt-to-equity ratio | Equity provider(s) | Debt provider(s) |
|---|---|---|---|
| **Olkiluoto 3** | 75:25 | • Consortium of electro-intensive companies | • Commercial banks |
| **Vogtle 3 and 4** | 0:100 | • Georgia Power<br>• OPG<br>• MEAG Power<br>• Dalton Utilities | • n/a |
| **Barakah** | 80:20 | • ENEC<br>• KEPCO | • UAE government<br>• Korean EXIM<br>• US EXIM<br>• Commercial banks |
| **Akkuyu** | n/a | • Rosatom | • Commercial banks |
| **HPC** | 0:100 | • EDF Energy<br>• CGN | • n/a |
| **Sizewell C** | TBD | • EDF Energy<br>• UK government<br>• Additional investors TBD | • TBD |
| **Paks II** | 80:20 | • Hungarian government | • Russian government |
| **Dukovany 5** | 98:2 | • ČEZ | • Czech government |

In other words, there is no single formula, and a universal financing mechanism cannot be applied across all nuclear new builds, underscoring the importance of tailored approaches based on the unique circumstances of each nuclear project.

### *Sources of equity financing*

In the case studies reviewed, equity financing for nuclear power plants come from three principal entities, namely i) the government, ii) the vendor, and iii) utility consortiums. In addition, other approaches involve a combination of equity financing from these three entities to support financing and can be grouped in five categories described below and illustrated in Figure 3.1:

a. **Utility or utility consortium**: A utility, such as ČEZ for Dukovany, can directly invest in a nuclear new build project. In addition, utility consortiums represent a collaborative effort among multiple electricity utilities with the need for new nuclear power plant builds. This form of equity investment is market-driven and may or may not involve additional governmental support measures. As demonstrated by both the Olkiluoto and the Vogtle projects, the alignment of strategic interests among members of a utility consortium is essential for the success of a project, particularly to address potential challenges during construction.

b. **Vendor**: Vendor financing is a financing approach whereby the reactor designer also offers equity investment for the power plant project. When feasible, this model is often accompanied by a streamlined package encompassing financing, reactor technology, EPC and operational support. In the case of Akkuyu, the equity investment was from the vendor, Rosatom. An equity investment from the vendor strengthens its incentives to mitigate for the risks of delays and cost overruns during construction.

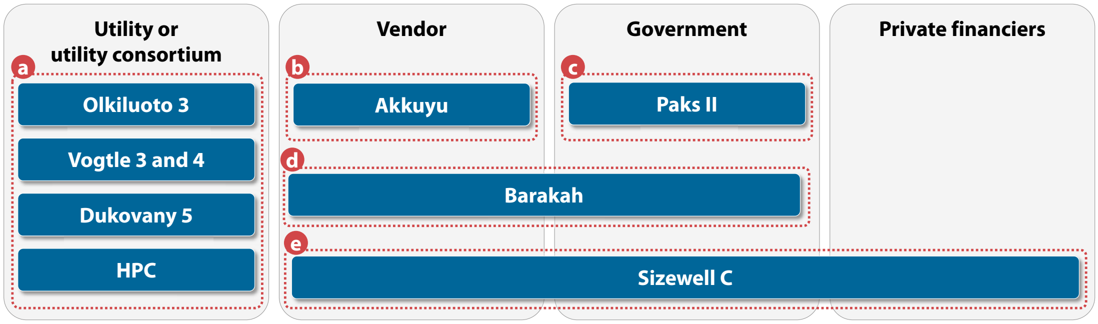
c. **Government**: Governments play a significant role in financing nuclear projects, thereby sharing the risk associated with nuclear infrastructure development. By committing equity investment, governments demonstrate their commitment and willingness towards project development. Notably, the Hungarian government provided a 100% equity investment in Paks II. This can contribute to fostering a conducive environment for private investors, potentially alleviating political risk concerns and attracting further investment.

d. **Government and vendor**: This hybrid financing model combines equity investments from both the vendor and the host country's government. For instance, Barakah received equity investments from KEPCO, the vendor and the UAE government through ENEC. The partnership between KEPCO and ENEC reflects a collaborative effort between the Korean and UAE governments.

e. **Government, vendor and private financiers**: A diverse investment group signifies a balanced risk-sharing approach, encouraging private sector participation. The Sizewell C project showcases a financing scheme that involves equity investment from multiple sources. Although plans are still underway, Sizewell C aims to finalise its equity investment structure through the combination of equity financing of the vendor, government and private financiers.

As equity investments result in more risk-taking compared to debt financing, the financiers in the cases examined were limited to those able to withstand the given investment conditions. It is noteworthy that the current equity financiers were involved in the project for a range of strategic objectives. For instance, governments tend to participate in the projects to support energy policy objectives, while utility consortiums make equity investments to secure long-term access to competitive and low-carbon electricity.

Figure 3.1: **Equity financing schemes**




Vendors can also play an important role in the financing of nuclear power plant projects. For several case studies reviewed in this report, the offer of the reactor vendor was not limited to technology and extended to equity financing. As shown in Table 3.2 below, KEPCO, Rosatom and EDF have all provided equity financing in their respective projects. However, vendors' ability to provide equity balancing will remain constrained by the size of their balance sheets compared to the financing requirement of the nuclear projects. For example, EDF indicated that it would not be in a position to provide for Sizewell C the same level of financing that it had committed for Hinkley Point C, leading in part to the development of the RAB model to attract additional sources of equity financing.

Table 3.2: **Equity providers of nuclear new builds**

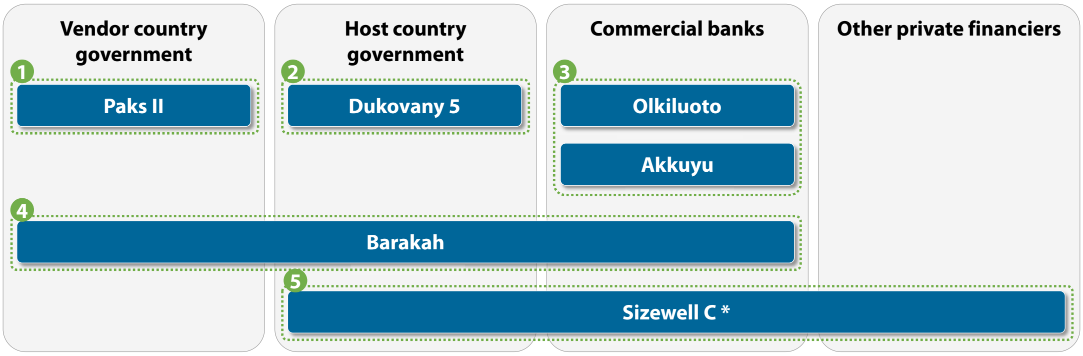
| | Equity provider(s) | Number of equity provider(s) | Vendor equity financing |
|---|---|---|---|
| **Olkiluoto 3** | • Consortium of electro-intensive companies | 60+ | No |
| **Vogtle 3 and 4** | • Georgia Power<br>• OPG<br>• MEAG Power<br>• Dalton Utilities | 4 | No |
| **Barakah** | • ENEC<br>• KEPCO | 2 | Yes |
| **Akkuyu** | • Rosatom | 1 | Yes |
| **HPC** | • EDF Energy<br>• CGN | 2 | Yes |
| **Sizewell C** | • EDF Energy<br>• UK government<br>• Additional investors TBD | TBD | Yes |
| **Paks II** | • Hungarian government | 1 | No |
| **Dukovany 5** | • ČEZ | 1 | TBD |

## *Sources of debt financing*

Debt financiers identified in this report can be grouped into four different entities – namely the governments of the host country and of the vendor, commercial banks and other private financiers. Some projects have employed a combination of debt financiers, while other projects have raised zero debt on a project level. Those projects can be grouped in five categories described below and illustrated in Figure 3.2:

1. **Vendor country government**: Governments of the vendors contribute to debt financing as they facilitate the exports of their domestic products and services. Notably, the Korean and Russian governments have provided debt financing in conjunction with the export of reactors from their respective state-owned vendors. For the Barakah plant, for example, the Korean EXIM contributed to the debt financing to support the project of KEPCO.
2. **Host country government**: Host country governments play a significant role in providing financing for nuclear power plant projects. Their involvement is more geared towards providing riskier financing through equity investment but may also provide debt financing. A notable example is Dukovany 5 nuclear power plant, where the Czech government facilitated the development of the plant through financing most of the debt of the project. The government went a step further and provided a 0% interest rate scheme for the construction stage in order to alleviate the financial burden during the development period.
3. **Commercial banks**: Loans from commercial banks were deployed in a number of nuclear power plant projects in the case studies included in this report but the involvement of the banks themselves has been somewhat limited. Significant commercial debt financing was leveraged in the case of Olkiluoto 3, which was rather exceptional.
4. **Vendor and host countries with commercial banks**: The Barakah nuclear power plant demonstrates the collaborative effort involving host country, vendor country and commercial banks in debt financing. The UAE government served as an important financier by providing the majority of the project's debt financing and offering a government loan guarantee.
5. **Host country government, commercial banks and other private financiers**: The Sizewell C project is looking to attract significant debt financing from commercial banks and other private financiers, with additional contributions from the UK government being considered in order for the project to reach final investment decision.

Figure 3.2: **Debt financing schemes**




Note: Sizewell C is currently looking at diverse options including loans from commercial banks, public bonds and ECA finance. Vogtle 3 and 4 and Hinkley Point C have been financed by 100% equity.

As noted in Table 3.3 below, the Vogtle 3 and 4 and HPC projects took a different approach by solely relying on equity financing. In these cases, the debt was accounted for on the balance sheets of the equity providers and not at the project level. Some projects were also able to receive financing from pure financial market players (i.e. commercial banks), despite the low contributions in total financing.

Table 3.3: **Debt financing for nuclear new builds (% of total debt financing)**

| | Public debt providers | | Private debt providers |
|---|---|---|---|
| | Host country | Vendor country | |
| **Olkiluoto 3** | - | - | International commercial banks (100%) |
| **Vogtle 3 and 4** | - | - | - |
| **Barakah** | UAE government (83%) | Korean EXIM (10%)<br>US EXIM (3%) | International commercial banks (1%) |
| **Akkuyu** | - | - | Russian commercial banks (100%) |
| **HPC** | - | - | - |
| **Sizewell C** | UK government (TBD) | - | TBD (TBD) |
| **Paks II** | - | Russian government (100%) | - |
| **Dukovany 5** | Czech government (100%) | - | - |

## Key findings on sources of revenue

While there are significant variations among the case studies in terms of financing sources, a greater degree of alignment can be noted in terms of sources of revenue.

Most nuclear power plants introduced in this study secured a long-term power purchase contract before the construction of the facility. Olkiluoto and Vogtle 3 and 4 were planned to sell their electricity to the consortium of utilities that had funded the project. HPC and Dukovany 5 projects will derive their revenues from a CfD formula. In the cases of Barakah and Akkuyu a governmental entity had promised a PPA with the nuclear power plant, despite the differences in contracted capacity and term duration. Lastly, Sizewell C also had a contract in place through the RAB model, to be activated during the operational phase of the plant.

Of all the projects, Paks II could be viewed as the exception where the project agreed to sell the produced electricity to the wholesale market in order to comply with the European Commission's approach to competition policy.

Table 3.4: **Long-term contracts of new nuclear builds**

| | Olkiluoto 3 | Vogtle 3 and 4 | Barakah | Akkuyu | HPC | Sizewell C | Paks II | Dukovany 5 |
|---|---|---|---|---|---|---|---|---|
| Regulated revenues | Investor offtake (Mankala) | Rate base regulation | Power purchase agreement | Power purchase agreement | Contract for difference | Regulated asset base | | Power purchase agreement |
| Unregulated revenues | | | | | | | Wholesale market | |

## Key findings on risk allocation

In the analysis of risk allocation across the projects, risk-specific heat maps have been detailed to review the five risk categories and six categories of stakeholders addressed in the case studies. The projects have been arranged in chronological order from left to right based on the respective national project announcements.

### Two key findings on risk allocation

These risk-specific heat maps across projects yield a number of key findings that are detailed in this section. The two most important findings are the following:

- **Key finding on risk categories**: Construction risk entails the highest degree of complexity and impacts the broadest range of stakeholders.
- **Key finding on risk allocation among stakeholders**: Equity providers face the most significant and diverse risk exposure among the six stakeholders.

As such, to ensure the successful implementation of nuclear initiatives, it is crucial to devise strategies aimed at first mitigating construction cost overruns and project delays, while creating incentives that foster an attractive investment framework for equity providers.

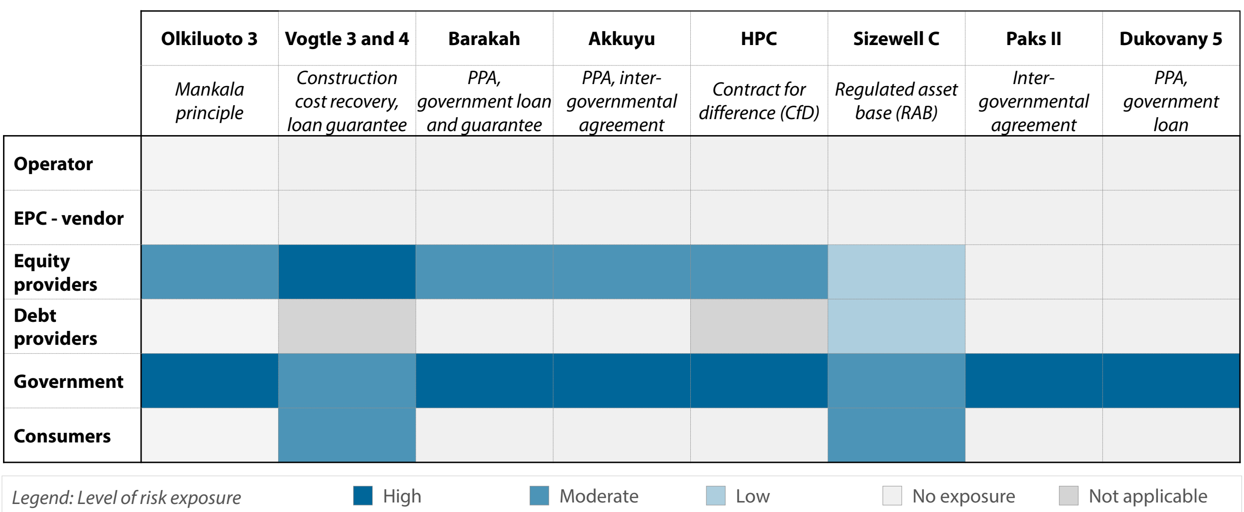
## *Comparison of risk allocations per risk category*

### *Political and regulatory risks*

Equity providers and governments bear political risks across many models. Governments mainly assume the political and regulatory risks, even providing explicit risk coverage measures in some cases. The UK government provided the Secretary of State Investor Agreement for HPC and the Czech government supported Dukovany 5 with the Change of Law Protection.

The Vogtle 3 and 4 and Sizewell C projects act differently, with some of the political and regulatory risks being allocated to debt providers and consumers. This reflects the fact that both projects take place in a regulated market environments that allocate a large share of the project risks to consumers.

Figure 3.3: **Political and regulatory risks allocation**

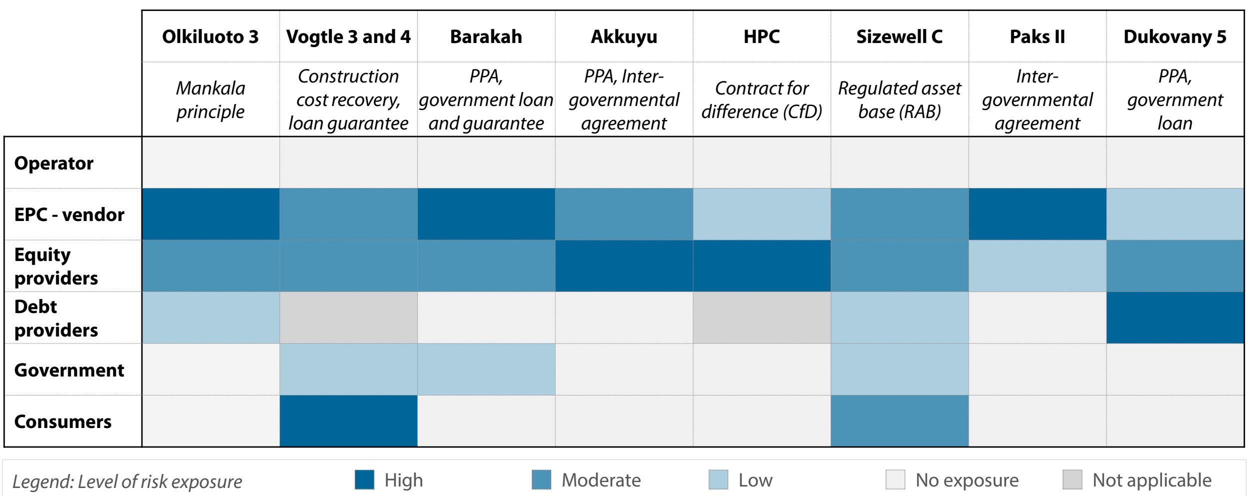


### *Construction risks*

Generally, across the various financing frameworks, a wide range of stakeholders carry at least some of the construction risks. The number of stakeholders involved for a given project can add complexity and contribute to the challenge of devising strategies to effectively mitigate and allocate those risks.

Equity providers, EPCs and/or vendors play a central role in carrying a portion of the construction risks. Most of the nuclear construction projects reviewed in this publication were under a fixed price turnkey contract, which tend to assign a significant share of the construction risk to the EPC and/or vendor. This was particularly the case for the Olkiluoto 3 and Paks II projects. For other projects, these EPCs and/or vendors were also the entities that provided equity investment to the projects. In cases like Vogtle and Sizewell C, partial construction costs were distributed to the consumers' electricity bills through the RAB and NCCR tariff frameworks respectively. Last but not least, Akkuyu and HPC were the only two projects where the equity investors took most of the construction risks, in both cases in large part because government was not in a position to take some of this risk.

Figure 3.4: **Construction risks allocation**



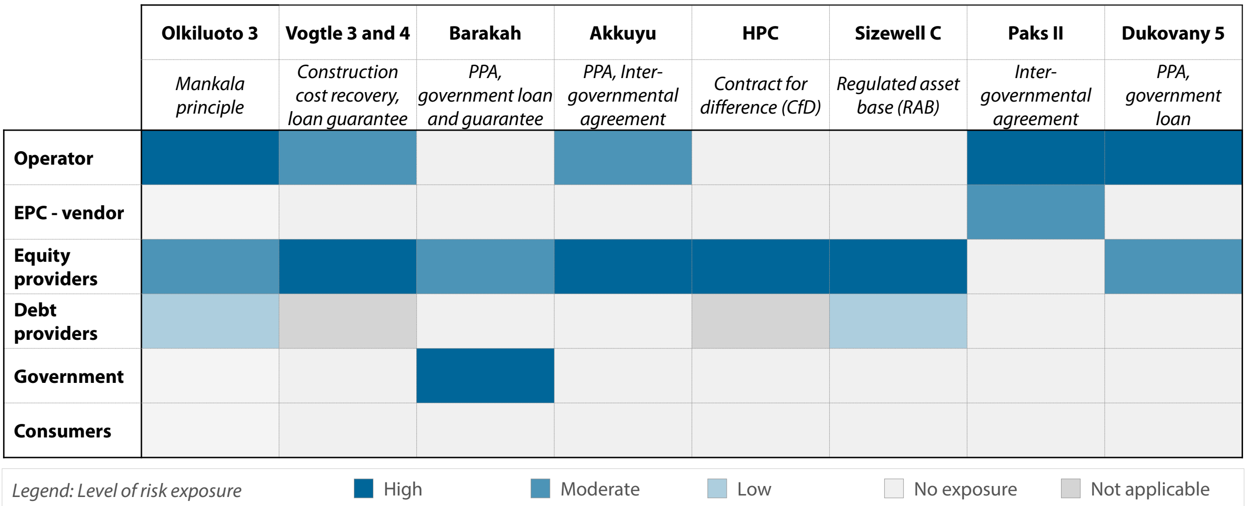

### *Operational risks*

The allocation of operational risk is highly variable across financing frameworks. Operators are designated as the main responsible entity for running the nuclear power plants, but costs are typically borne by equity providers. The risk exposure of these equity providers is proportionate to their equity stake in the projects. In cases where the equity provider and the plant operator are the same entity or vertically integrated, operational risks may be consolidated at the level of the equity provider.

Conversely, it is worth noting that operational risk is the only risk category for which consumers do not bear any of the risk directly. Similarly, government are not responsible for this risk category except in the case of the Barakah project. Consumers may bear some indirect exposure to operational risk in some liberalised electricity markets if, for instance, low operational performance causes periods of outages that lead to higher electricity prices.

Last but not least, specific arrangements exist for the Paks II project where, through a dedicated contract to support plant operations, the operation risks will be shared between the project company and the EPC company.

Figure 3.5: **Operational risks allocation**

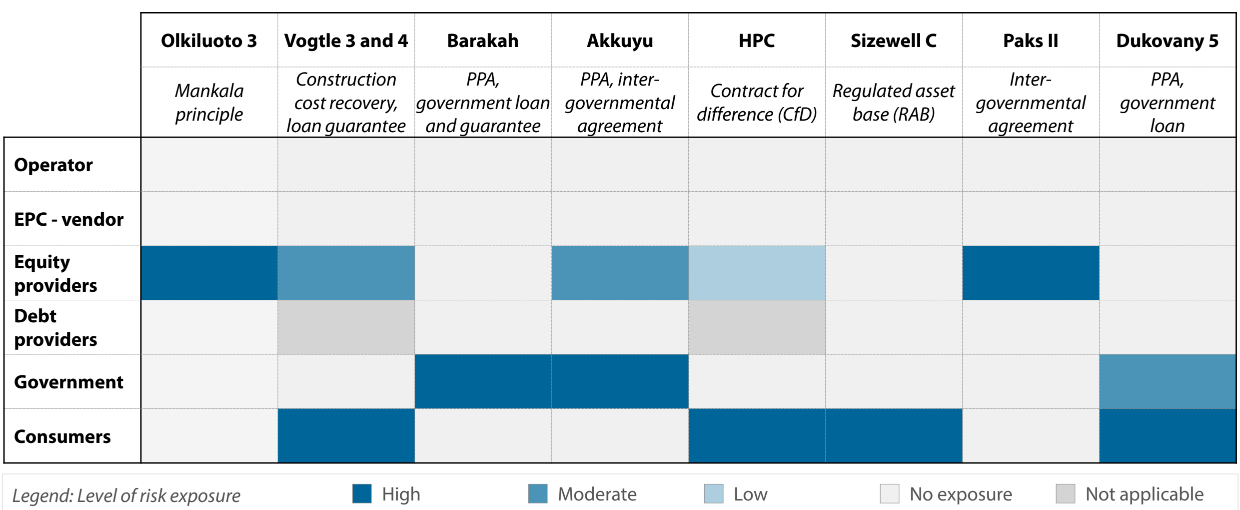



*Electricity market risks*

In most cases, the risks associated with market volatility are either transferred directly or indirectly to consumers through their electricity bills or taken directly by the government through a long-term PPA designed to safeguard other stakeholders from electricity market risks. For instance, both Akkuyu and Barakah are examples of projects where governments take a significant share of the electricity market risks. In the case of Barakah, the government assumes all this risk through a long-term PPA. Conversely, in the case of the Sizewell C project, the consumers bear the totality of the electricity market risks.

In some instances, equity providers have assumed part of the electricity market risks through specific agreements. For example, for the Olkiluoto 3 project, the co-operative offtake agreement between the equity providers and TVO means that the former are fully responsible for the electricity market risks. Similarly, in the case of Paks II, the project is required to recover its investments through the electricity markets, which means that the equity providers are also responsible for market risks.

Figure 3.6: **Electricity market risks allocation**



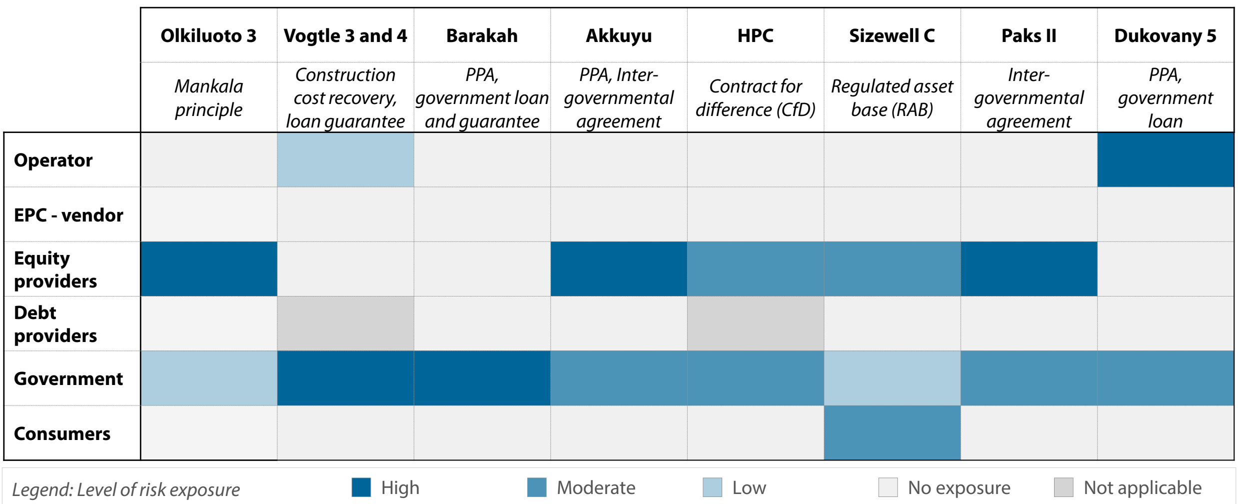
*Decommissioning and waste management risks*

Generally, across the various financing frameworks, financial risks and liabilities for the back end of the fuel cycle are shared between governments and equity providers. As with operational risks, the allocation of decommissioning and waste management risks to either the operators or the equity providers depends on whether the two entities are vertically integrated.

Specific arrangements can be noted for the Sizewell C projects, where the RAB model leads to consumers assuming a moderate share of the decommissioning and waste management risks.

It is also worth noting that in several instances governments also assume the residual risks. Residual risks are defined as the risks that a project would still bear after risk mitigation strategies have been implemented. In practice, these risks often correspond to low-probability but high-impact risks. As the "insurer of last resort", governments take on this responsibility to ensure the long-term safety and stability of nuclear power operations.

Figure 3.7: **Decommissioning and waste management risks allocation**




## Risk allocation among stakeholders

In parallel, a clearer pattern can be observed when it comes to the allocation of risks among key project stakeholders, with the main differences essentially linked to project-specific contexts. Table 3.5 below provides a summary of the risk allocation among stakeholders as well as their overall level of risk exposure across the case studies.

Table 3.5: **Summary of risk allocation among stakeholders**

| | Range of risk exposure across the case studies | Political and regulatory risks | Construction risks | Operational risks | Electricity market risks | Decommissioning and waste management risks |
|---|---|---|---|---|---|---|
| **Operators** | *Low to moderate* | | | | | |
| **EPC and/or vendor** | *Moderate to high* | | | | | |
| **Equity providers** | *Low to high* | | | | | |
| **Debt providers** | *Low* | | | | | |
| **Governments** | *Low to high* | | | | | |
| **Consumers** | *Low to high* | | | | | |

This analysis yields a number of observations about the relative role that each stakeholder plays in terms of risk allocation and the overall range of risk exposure across the case studies:

- **Operators**: Operators have a low to moderate overall level of risk exposure and are responsible for the operations of the nuclear power plants after commissioning. Often the scope extends to decommissioning and waste management.
- **EPC and/or vendors**: EPC and/or vendors have a moderate to high level of overall risk exposure. However, this exposure is limited to the construction of the power plant. There were some cases where the EPC and/or vendors were not able to absorb the cost overruns of the project, which led to severe restructuring as well as involvement of the final shareholder of the EPC and/or vendor.
- **Equity providers**: Equity providers have a low to high overall level of risk exposure and can be exposed to all the risks associated with a nuclear power plant. Equity providers often also engage in a project as other entities (i.e. operator, EPC and/or vendor, government).
- **Debt providers**: Debt providers have a low level of risk exposure due to the priority of debt repayment and the secured nature of their investments. Additionally, debt providers often benefit from government loan guarantees that provide an added layer of security and encourage debt providers to participate with greater confidence. Their risk exposure is limited to construction and operational risks.
- **Governments**: Governments have a low to high overall level of risk exposure and can be exposed to all the risks associated with a nuclear power plant. The first role of the government is to establish policy frameworks, which extends to radioactive waste management policies. However, a number of projects also highlight a greater role for governments in terms of both financing support and risk sharing.
- **Consumers**: Consumers have a low to high overall level of risk exposure and can be exposed to all the risks associated with a nuclear power plant except for operational risks. Consumers are often exposed to a high share of market volatility risks with costs channelled through their electricity bills. It is worth pointing out that even in cases where consumers are not directly exposed to these risks, some risks may indirectly be partially channelled back to them. For example, construction risks related to delays and potentially completion may leave consumers exposed to more expensive sources of electricity.

## Key findings on the roles of government for nuclear financing

The case studies underline the large policy toolkit that governments have at their disposal to support nuclear new build projects. Table 3.6 below provides a stocktaking of key policy support measures that have been implemented or are being considered in the case studies reviewed by this publication. The table organises these policy measures into three categories:

i. direct financial support;

ii. indirect financial support; and

iii. non-financial support.

Direct financial measures cover both equity investment and debt financing. Public equity investment is being considered for the Sizewell C and Paks II projects and public debt financing from the national governments has been used for the Barakah project and is being considered for the Dukovany 5 project. The other projects did not receive direct financial support.

Indirect financial support includes a range of support measure: Both the Vogtle 3 and 4 and Sizewell C projects include construction cost recovery mechanisms. Long-term power purchase agreements have been widely implemented in different forms for Barakah (PPA), Akkuyu (PPA), Dukovany 5 (PPA) and Hinkley Point C (CfD). Loan guarantees have been used for Vogtle 3 and 4 and offered for Hinkley Point C. Export credits have been used for Olkiluoto 3 and Barakah. Last but not least, fiscal policy is relevant to the Olkiluoto 3 to the extent that the Finish Mankala model provides a legal framework to establish a non-profit limited company. Taken together, all the projects received some form of indirect financial support.

Non-financial support measures are more far reaching. To a large extent, measures such as workforce development, legislative and licensing frameworks, among others, have been used in all the projects reviewed in this publication. However, some measures have only been applied to specific projects. For instance, change of law protection has been proposed for just two projects: Hinkley Point C and Dukovany 5. Similarly, intergovernmental agreements have been implemented for selected projects based on Russian nuclear reactor designs – Akkuyu and Paks II – and are a central feature of those financial frameworks.

This stocktaking exercise highlights that government policy support for new nuclear projects goes well beyond direct financial measures. A range of indirect measures, including cost recovery mechanisms, power purchase agreements and loan guarantees will contribute – often significantly – to the overall financing framework. The same also applies for non-financial measures, particularly legislative and regulatory measures. Those measures are often necessary conditions for investment decisions as they underpin the allocation of key project risks. Notably, a handful of countries have engaged in sovereign-level agreements to secure financing from external parties, while also fostering local content.

These policy support measures remain closely linked to national and industrial contexts. Therefore, governmental support cannot be guided by a standardised playbook. In particular, governments may have different abilities to provide direct or indirect financing support based on the state budget situation and other competing priorities. The role and relative importance of this financial support measures will be further influenced by the possibility to leverage private capital for the project, which will itself be largely driven by the industrial context.

In some contexts, a comprehensive combination of indirect financial measures and non-financial support measures can limit the need for direct financial support from governments and effectively support the success of nuclear projects. In this context, policymakers should strive to put in place non-financial measures early in the project development stage as those will be prerequisites for private investment decisions. For instance, long-term contracts may play an important role in securing commercial loans, acting as a risk mitigating tool for debt financiers.

Table 3.6: **Summary of policy measures across the case studies**

<table>
<tr><th colspan="2">Financial</th><th rowspan="2">Non-financial</th></tr>
<tr><th>Direct</th><th>Indirect</th></tr>
<tr><td>• Equity investment<br>• Debt financing</td><td>• Construction cost recovery mechanism<br>• Long-term power purchase contract<br>• Loan guarantee<br>• Export credit<br>• Fiscal policy</td><td>• Policy support and regulatory stability<br>• Provision of infrastructure and site<br>• Inter-governmental agreements<br>• Final risk taker for residual risks<br>• Change of law protection<br>• Workforce development<br>• Electricity market design<br>• Legislative frameworks<br>• Technology transfer<br>• Licensing frameworks<br>• Waste management</td></tr>
</table>

## Key findings on the role of private financing for recent and future nuclear projects

### *Recent projects have showed limited private interest and increasing governmental involvement*

The case studies showcase how governments have attempted in recent nuclear projects to incentivise private investments through measures such as favourable regulatory frameworks, loan guarantees and tax incentives.

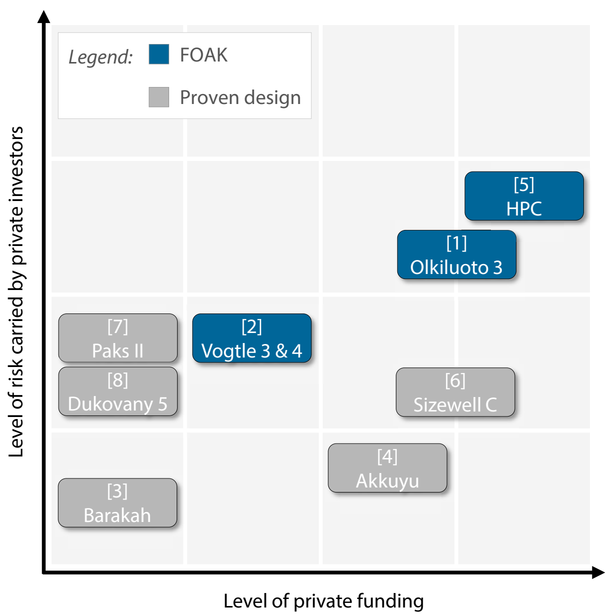
To better understand the role of the private sector in the financing of the eight nuclear new build projects reviewed in this report, Figure 3.8 below summarises the decisions made for each project in terms of the level of private sector involvement. The analysis in the figure focuses on two key aspects:

- **Level of private financing**: On the horizontal axis, the share of private financing originating from either debt or equity is reported. This assessment is based solely on the source of financing. For example, private debt financing that benefits from government loan guarantees would be considered here as private financing.
- **Level of risk carried by private investors**: On the vertical axis, this assessment of risk transfer to private investors is based on the risk heat maps of each project, aggregating the five categories of risk into one overall assessment.

For instance, nuclear new build projects on the top right part of the figure (e.g. Hinkley Point C) have relied more on the private sector in terms of risk transfer and financing. Conversely, nuclear new build projects on the bottom left of the figure (e.g. Barakah) have relied primarily on the public sector for risk transfer and financing.

Figure 3.8 makes an additional distinction between first-of-a-kind (FOAK) projects and projects based on proven designs. Here FOAK is defined as projects that are not based on a reference plant and that do not rely on a domestic supply chain with recent experience in nuclear construction.

Figure 3.8: **Comparison of risk allocation and ownership between the public and private sectors**




Note: Numbers on the boxes indicate the order of which final investment decisions have been or are expected to be announced.

This analysis shows that some degree of public support either in terms of financing or risk transfer is part of the financing frameworks and strategies for all projects reviewed in this publication. Recent projects are also characterised by an increasing level of public sector involvement in financing, both in terms of sources of financing and risk transfer. Several governments have expanded their support by offering various forms of financing, long-term power contracts, or arrangements with other sovereign entities.

Within the projects analysed, private entities are always involved in financing, but their share of participation remains limited. Notably, equity and debt providers are primarily comprised of governmental entities (e.g. governments, export-import banks, state-owned utilities) and private entities incentivised by strategic considerations (e.g. vendors, utility consortia). The only purely financially motivated investors without ties to the project have been commercial banks. Other financiers, such as private equity funds, infrastructure funds, multinational development banks and others which commonly participate in large-scale infrastructure projects have not been involved so far in any of the projects reviewed.

Last, it is relevant to comment on the levels of risk transfer for the Olkiluoto, HPC and Sizewell C projects. All three projects are based on the EPR design and all have or are expected to secure a high level of private financing. Among these three projects, the Sizewell C project is the first EPR project to be based on a proven design (i.e. based on a reference plant) which will also be able to leverage recent nuclear supply chain experience in nuclear construction. It is expected that this project will come with a lower risk profile that would be more attractive to private investors. However, Sizewell C is also currently expected to have a lower allocation of risk to the private sector. This can be explained both by:

i. the constraints on the balance sheets of EDF, the main investor in the EPR project at HPC; and

ii. the fact that private investors would still require a high return to agree to take a substantial share of the project risks. This risk premium leads to a high cost of capital, which directly impacts the costs of electricity for the project.

The solution currently proposed by the UK government will rely on the implementation of a regulated asset base (RAB) model. This model will allocate a large share of the risk to consumers and taxpayers, resulting in a lower cost of capital for the project and therefore a lower cost of electricity for final consumers.

### *Future projects could see higher levels of private sector involvement as nuclear reactor designs and the supply chain gain experience*

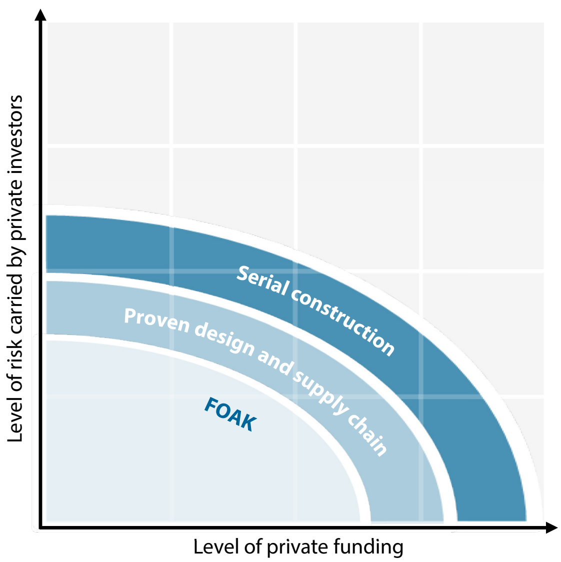
Building on the comparative analysis of the financing frameworks for recent nuclear new build projects, it is possible to derive some guiding principles about the role of public and private financing for future projects:

First, FOAK projects can be expected to continue to require extensive public-private partnership, with a sizeable role for the public sector, primarily in terms of the level of risk allocation and, to a lesser extent, the contribution to financing.

Second, as nuclear projects achieve higher levels of design and supply chain maturity, a larger role can be expected for the private sector, both in terms of risk allocation and contribution to financing. This is largely driven by the fact that design and supply chain maturity will reduce key project risks, particularly those associated with construction (NEA, 2020). Figure 3.9 below illustrates this argument, not to prescribe some level of private financing moving forward but rather to underline that – generally speaking – this role for private actors can be expected to increase with the level of design and supply chain maturity. At the same time, it can be expected that some limit will remain when it comes to risk allocation to the private sector, particularly specific residual risks related to changes of policy.

Third, building on mature designs and proven supply chains, serial construction will be associated with further reductions in construction risks (NEA, 2020) and could therefore provide additional opportunities to increase the role of the private sector in nuclear financing. This is expected to apply both to the serial construction of large-scale new build and small modular reactors (SMRs). In that respect, it is worth noting that several arguments can be put forward on the benefits of SMRs from a financing perspective, particularly due to expectations for shorter construction lead-times, as well as lower capital requirements per reactor, leading to a higher affordability for a larger set of financiers. However, these arguments remain speculative for the time being and further analysis will be required to better understand to which extent SMRs could unlock distinctively different financing frameworks with a larger role for the private sector.

Figure 3.9: **Potential risk and ownership transfer to the private sector for future nuclear new build projects**




### *The role of private investment must be considered in conjunction with the nuclear project life cycle*

Nuclear new build financing is also not static across the project life cycle. While this point was not a core part of the case studies analysis, anecdotal evidence gathered in the course of the case studies highlights that nuclear projects exhibit unique risk profiles, lead times and cash flows at different stages of the project life cycle, making them attractive to different investor types at different stages. This characteristic impacts the available capital and, consequently, financing frameworks should take into consideration the risk-return preferences of different investors.

Figure 3.10 below provides a high-level assessment of this level of interest of different sources of private equity and private debt financiers for nuclear new build financing across the project life cycle. It also provides an assessment of the funding from these different sources of equity and debt financing:

First, there will remain some limitations to private finance when projects are under development. This private sector financing is expected to be limited to strategic industrial partners providing equity investments or shareholders providing loans to support project development. In both cases, the funding potential will be by nature project-specific. As a direct consequence, for projects where both sources of financing are limited or not available, a specific role can be expected for governments to either step in directly or to offer specific incentives to attract private investment. For example, for projects under discussions such as Dukovany 5 in

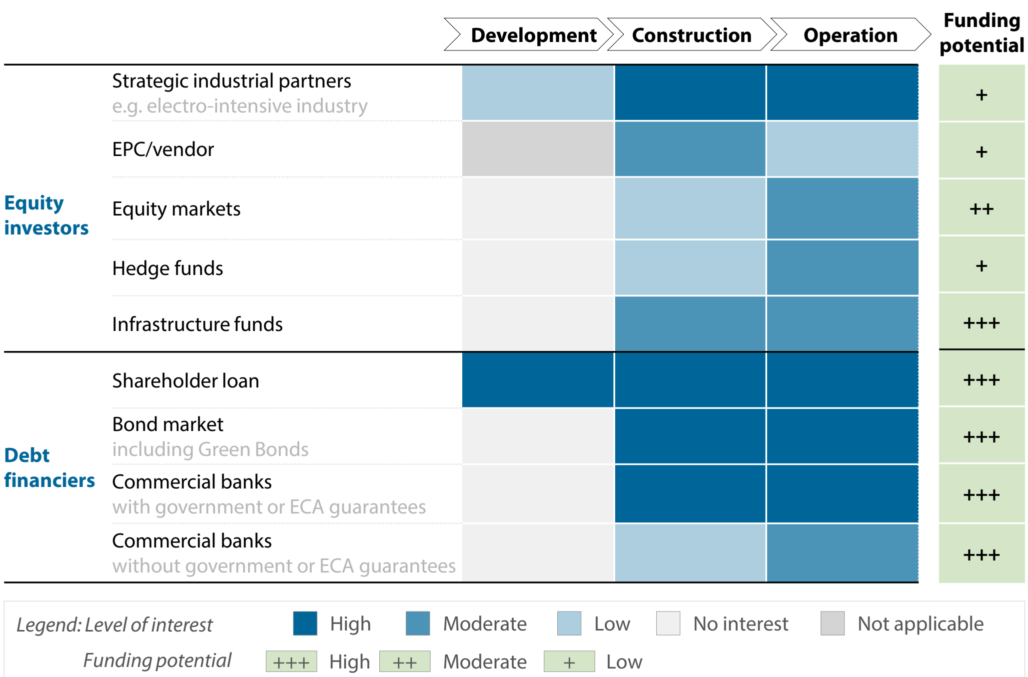
Czechia and Sizewell C in the United Kingdom, the government provided such financial support to assist the projects prior to their final investment decisions.

Second, a number of additional sources of financing can be expected once projects reach their final investment decision. For equity financing, EPC and/or vendors but also financial institutions such as pension and infrastructure funds could contribute to financing. Those financial institutions could further provide important contribution to the overall financing frameworks. Again, Sizewell C in the United Kingdom provides instructive insights with such funds expected to directly contribute with equity financing. In parallel, additional sources of debt financing can be expected, particularly where governments or export credit agencies provide guarantees to the lenders. Green bonds could also catalyse additional debt financing from the private sector in jurisdictions that include nuclear in environmental, social and governance (ESG) taxonomy.

Third, it can be expected that this interest will increase once a nuclear power plant enters commercial operation as the completion of construction significantly reduce the project risk profile. This is a central point for any policy discussion on nuclear financing frameworks as it implies that sizeable opportunities can be expected for refinancing nuclear projects once in operation. This opportunity for refinancing has in turn some further potential implications for nuclear financing frameworks:

- Some rules may need to be set in advance regarding how potential benefits from refinancing would be shared between parties and particularly between investors, consumers and taxpayers. For example, the financing framework for the Hinkley Point C project in the United Kingdom specifically includes provisions in case of refinancing once the project reaches commissioning. Those rules are set as part of the contract for difference in order to ensure that any benefits from being able to refinance the project with a lower cost of capital are shared between investors and consumers.
- For projects that decide to rely primarily on public sources of financing during construction, governments may be able to recover those investments shortly after construction.

Figure 3.10: **Potential role of the private sector for future nuclear new builds**



# Chapter 4. Key insights on nuclear financing frameworks

The nuclear financing case studies described in earlier chapters provide a number of key insights on the drivers and key features of different financing frameworks that have been implemented in recent years for nuclear new build projects. The comparative analysis of these models highlighted a number of areas of convergence across the case studies, for instance when it comes to the use of some of long-term contracts to secure future revenue streams and mitigate electricity market risks for investors. This analysis also sheds light on areas of divergence, particularly for the sources of debt and equity financing, the direct and indirect roles that government can play, or the allocation of construction risks across the different stakeholders.

Building on these key findings, a number of key insights emerge that should be carefully considered upfront for all future nuclear energy projects.

## Key insight 1: Financing frameworks remain closely linked to national and industrial contexts

Financing frameworks do not exist in a vacuum. Rather, they are deeply intertwined with national and industry contexts. From a policy perspective, this means that lessons learnt need to be contextualised before they can be transferred to another setting. To do so requires a solid understanding of how a financing framework connects to policy and industrial environments.

For example, while the RAB model in the United Kingdom is currently attracting significant interest, it is worth pointing out that an important factor driving investors' confidence in this approach is the fact that the model has been used extensively for other infrastructure projects in the United Kingdom. Similarly, the Olkiluoto 3 project is underpinned by the Mankala model that has been used as a framework to finance most energy infrastructure projects in Finland over the last 50 years. On the industrial front, supply chain and design maturity, alongside utilities' technical capabilities and financial position will continue to be key drivers behind the choice of financial frameworks for nuclear new build projects.

## Key insight 2: Financing frameworks cannot solve structural problems caused during upfront project planning

As highlighted in Figure 4.1, long-term national commitment to nuclear energy and strong upfront project planning are key necessary conditions for devising and implementing successful frameworks for nuclear financing.

Consequently, when a nuclear project fails to reach final investment decision it may not necessarily be because there is a specific challenge or roadblock with financing *per se* but rather because discussions about nuclear financing unearthed more systemic issues with the project that need to be addressed first.

Figure 4.1: **Financing frameworks, national commitment and upfront project management**


## Key insight 3: De-risking construction is key to attracting additional sources of funding and to reducing the cost of capital

Across the different risks facing nuclear new build projects, those associated with construction cost overruns, delays and completion are the most significant. Consequently, these types of risks deserve the most attention when discussing the merits of different nuclear financing frameworks.

However, tackling construction risks implies some trade-offs. In particular, the case studies demonstrated the need to balance:

i. the ability to mitigate those risks before construction, and

ii. the ability to absorb them during construction.

On the one hand, financing frameworks should create incentives for stakeholders to minimise risks prior to construction, focusing in particular on those stakeholders that are best placed to do so. On the other hand, if risks do materialise during construction, financing frameworks should clearly account for the ability of different parties to face these risks and absorb them financially.

One key insight is consistent across all of the case studies in this publication: ultimately, all risks are largely born by either rate payers, i.e. consumers, and/or taxpayers, i.e. governments. Moreover, rate payers and taxpayers are ultimately best placed to absorb low-probability risks with high impacts, such as construction cost overruns.

This issue is now increasingly at the core of policy discussions on future nuclear financing frameworks, such as the RAB model currently under discussion in the United Kingdom or the financing model proposed for Dukovany 5 in Czechia. In particular, a direct consequence of allocating some of the construction risks to consumers will be a reduction in the risk premium required by equity investors, translating into a reduction of the cost of capital. Given the sensitivity of the cost of nuclear electricity generation to the cost of capital, consumers are ultimately expected to benefit from lower costs of electricity in return from taking a portion of the construction risks.

## Key insight 4: Aligning stakeholders' interests should remain an overarching principle

Last but not least, the importance of allocating risks between parties should not distract from the overarching objective of aligning stakeholders' interests. Nuclear energy involves significant financial, safety, environmental and geopolitical considerations, making it essential to engage over a long period a diverse set of stakeholders, including governments, safety authorities, local communities and investors.

While a key aspect of nuclear financing frameworks is to formulate clear decisions about risk allocations, this process should be implemented in a way that keeps in sight the need to ultimately align stakeholders' interests through efficient contracting. Doing so is an essential condition for overall project success and should therefore remain a key consideration when discussing the relative merits of different nuclear financing models.

This principle will promote transparency, foster responsible decision making and ultimately support the successful deployment of nuclear energy as a component of future low-carbon energy mixes.

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# Effective Frameworks and Strategies for Financing Nuclear New Build

Scaling up investment flows in nuclear energy is one of the major challenges for OECD and NEA countries that have decided or are considering the construction of nuclear power plants. This report offers a comprehensive review of global financing strategies, aiming to establish a common vocabulary and basis for comparative analysis to identify and discuss key lessons learnt about the relative merits of different strategies to finance nuclear projects. While there are no simple solutions for financing new nuclear projects, this report helps identify the "building blocks" that policymakers and private sector decision makers can leverage to help finance a tripling of nuclear energy by 2050.

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