Master of Science in Corporate Finance

Chair of Advanced Corporate Finance

Modelling the Impact of Financing Structures on the Bankability of Small Modular Reactors: a Monte Carlo Approach

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Introduction

The global energy sector sits at a critical crossroad between ensuring national energy security and embarking on a significant decarbonisation of the economy to address the urgent threats of climate change. For decades, energy policy discussions in many Western countries have term focused on a renewable energy transition, specifically from wind and solar. The variability (or intermittency) of solar and wind technologies and most recently, the geopolitical shocks that revealed the vulnerabilities of global fossil fuel supply chains, have now elevated discussions of energy system resilience and diversification of energy supply. In this space, nuclear energy which has been all but excluded from many countries' strategic discussions, is experiencing a pronounced and multi-dimensional resurgence.

This momentum cannot simply be viewed as merely returning to the past, but rather it represents a reassessment of nuclear power's unique characteristics: the capacity to provide firm, dispatchable, low-carbon electricity at scale. The most tangible expression of this recognition was made political at the 28th Conference of the Parties (COP28) in 2023, where a coalition of over twenty countries, including the United States, France, and the United Kingdom, collectively pledged to work to triple global nuclear capacity by 2050. This commitment represented a clearly articulated transformation, placing nuclear energy firmly back into the vocabulary of a stable, net zero energy system.

However, that trajectory faces one significant historical barrier: the extreme difficulty of financing new nuclear power plants. The model that has predominated the last half century of nuclear was large-scale, gigawatt-class, light-water reactors. Despite technological verification, the projects have come to be associated with very high capital intensity, lengthy construction schedules, and continue to be exposed to the risk of large cost overruns and delays. Reference projects (for example, Olkiluoto-3 in Finland, Flamanville-3 in France, Vogtle-3 and -4) have experienced budget and schedule slippage in the range of two to three times original plans, resulting in a generalist risk aversion to these projects by investors and lenders. The literature is very clear: unless substantial state-led action is taken to mitigate and re-allocate risk, the private sector is unwilling to bear the financial exposure associated with these mega-projects.

Consequently, and within the context of a financing impasse, the nuclear industry is chasing technological innovation to represent an entirely new model of delivery and risk profile of new nuclear power. Within this movement, SMRs are leading the way, away from the conventional construction plant. The SMR model is based upon different economics: moving from *economies of scale* with large reactors, to *economies of volume* through both the serial, factory-built delivery of smaller, standardised and modular units. This approach has the potential to offer a wide range of valuable financial benefits to the industry, including absolute capital costs per project or unit being lower, seized construction time, lower risk on the construction site, and the ability to receive revenue from individual modules as they are brought online.

However, this compelling vision remains a commercially unproven hypothesis. The transition from expensive, high-risk First-of-a-Kind (FOAK) units to cost-competitive Nth-of-a-Kind (NOAK) units requires traversing an economic "valley of death". The initial SMR projects will inevitably bear the full cost of establishing new supply chains, qualifying novel designs, and navigating first-time licensing processes, making them significantly more expensive than their mature counterparts. his period of high cost and uncertainty presents a formidable barrier to private investment, as no single developer can be expected to single-handedly finance the learning curve for an entire industry. So, the key question is, how do we finance these initial projects so we can unlock the cost savings of mass production?

The success of the SMR revolution is not a technical question, it is a question of financing, and since financing the first projects is expensive and perceived as too risky from private capital, it is a political question. Recognising the structural incapability of private markets to finance nuclear output without some form of financial assistance from the state, governments have historically employed a range of interventions to render projects financially viable. Over time, this range has transitioned from the full state ownership and balance-sheet financing characteristic of the early nuclear period, to an increasingly sophisticated set of risk-mitigating frameworks seeking to solicit private capital. In liberalised electricity markets, particularly if projects are exposed to volatile wholesale electricity prices, the avenues provided to mitigate risk have become the most important determining factor in whether a project is bankable. In this regard, several models have emerged.

For instance, the Contract for Difference (CfD) model, used in the UK for the Hinkley Point C project, allows the generator to receive a long-term inflation-indexed strike price for the electricity it generates. Under a CfD model, the project developer is relieved of all wholesale market price risk since a government-backed contract will provide power at the strike price. Therefore, the project can rely on a consistent, stable revenue stream while reducing the cost of capital significantly. Another example is the Regulated Asset Base (RAB) Model. Again, this was developed in the UK for the proposed Sizewell C project. In the RAB model, the developer is allowed to earn a regulated return on its capital starting from the beginning of the construction period. This amount is financed via a small percentage of consumer electricity bills when the project generates electricity. This arrangement considerably eases the burden of a lengthy construction period which does not generate revenue creates in the financial statements of projects, therefore, pension and infrastructure funds find them more attractive. An alternative -Finnish model used for the Olkiluoto-3 project, is the Mankala (cooperative) model, where a consortium of large industrial electricity users owns the power plant. The shareholders do not receive dividends, they receive electricity at cost, pro-rata to their % ownership stake. This effectively removes market risk since the participants are a captive group of offtakers.

While these models have been applied to large-scale reactors, a significant area of uncertainty remains regarding their specific application to the unique risk profile of SMRs, particularly the critical FOAK-going-to-NOAK transition. The existing academic and policy literature has broadly addressed the technological potential of small modular reactors, but there is still a comprehensive, quantitative financial analysis absent assessing the bankability of SMRs under these different de-risking frameworks.

This thesis intends to respond to a critical gap in the research. Its objective is to provide a statistical assessment of the financial viability of small modular reactors. Therefore, the central research question addressed throughout this research is: Under what financial structures and policy frameworks can Small Modular Reactors become bankable investments, capable of attracting the private capital necessary for their widespread deployment?

To answer this question, this study builds a stochastic financial model. Using a Monte Carlo simulation approach, the model quantifies the financial performance and bankability of a representative SMR project under four distinct scenarios. The four scenarios exist at the intersection of two variables: the technology maturity level of using different cost levels (high cost for FOAK project compared to lower cost for NOAK project), and the revenue structure (using a regulated Contract for Difference designed to decrease project risk, versus a fully liberalised merchant market model). The Monte Carlo model simulated 100,000 possible outcomes for each scenario to derive probabilistic distributions of key project financial performance indicators, specifically Net Present Value (NPV), as the measure of value creation for equity investors, and Debt Service Cover Ratio (DSCR), a critical measure of creditworthiness from a lender's perspective.

The structure of this thesis is as follows: Chapter 1 provides an overview of the global nuclear energy market with specifics on the current global fleet, reactor technology trends, and motivations for the nuclear renaissance. Chapter 2 contains a general overview of the principles of nuclear project finance as an introduction to the broader discussion of risk, capital structure, and bankability. Chapter 3 describes the methodology and the empirical dataset used to define the key input parameters that encompass the operational, cost, and funding characteristics of an SMR project, and builds the empirical model to structure the Monte Carlo simulation. Chapter 4 presents and analyses the empirical results of the model, providing a scenario-by-scenario analysis of the financial performance of the project, alongside a discussion of the salient findings measured. The thesis concludes by summarising the findings, considering the implications for governments and investors interested in supporting the SMR transition to be as successful as possible, and discussing potential future research.

1. The Global Nuclear Energy Landscape

1.1. The resurgence of nuclear energy in a carbon-constrained world

The global energy sector is at a decisive moment in time and facing an urgent, dual dilemma: energy security and deep decarbonization to address climate change. In this context, nuclear energy is returning to prominence and experiencing a multi-dimensional resurgence. This "new era" for the technology marks a period of rebirth significantly distinct from the expansion driven by the 1970s oil crises, which was arguably driven by energy independence from volatile fossil fuel markets. Differently, today we are seeing a growing and complex interplay of factors driving the adoption of nuclear energy. Key drivers are the increasingly stringent climate policies, including the unprecedented commitment by members of the 28th Conference of Parties (COP28) to triple the world's nuclear capacity by 2050; the geopolitical shifts resulting from the rapid emergence of a number of new nuclear powers; disruptive emerging technologies such as Small Modular Reactors (SMRs), and the emergence of novel, large-scale demand from the digital economy for constant, carbon-free power.

Historically, nuclear energy has been defined by periods of rapid growth followed by stagnation, heavily influenced by both the Chernobyl and Fukushima accidents, which permanently eroded public confidence in the technology and tightened regulatory oversight. Hence, the current nuclear renaissance is not to be intended as a simple return to the past, but must be understood as a re-assessment of the intrinsic and unique characteristics of this energy source, notably, the ability to provide firm, dispatchable, and low-carbon power on a massive scale, making it a fundamental tool complement the variability of renewable sources, such as wind and solar, maintain a stable electric grid, and ensure a robust energy mix at a country level capable of realistically decarbonize our economies. This chapter seeks to lay the foundation for understanding the emerging nuclear era. The first part will be a quantitative assessment of the world's global nuclear fleet, looking at the status of operating, under-construction and planned reactors to understand the current situation and geographical layout.

The second part will be a deep dive into advanced technologies, focusing specifically on the paradigm shift of Small Modular Reactors (SMRs), the specialized use cases of microreactors, and the long-term trajectory underpinned by Generation IV reactors' design and development. Subsequently, the chapter analyses the primary drivers and prevailing trends shaping the industry, from the climate imperative and geopolitical competition to the evolution of economic models and regulatory frameworks.

The main takeaway from this review is that the case for a technical and political rationale to expand nuclear energy is strengthening, but the success of this new phase of development will depend on addressing complex financial challenges. The modern nuclear environment, with current technological, political and market risks, is multi-variate, and invalidates simple, deterministic financial analysis. This means complex, probabilistic analyses must be used instead. Consequently, this chapter concludes by arguing that to understand the financial future of SMRs and other advanced reactors, it is essential to employ advanced risk-based modelling techniques, thereby establishing the rationale and necessity for the core research of this thesis.

1.2. The current state of the global nuclear fleet

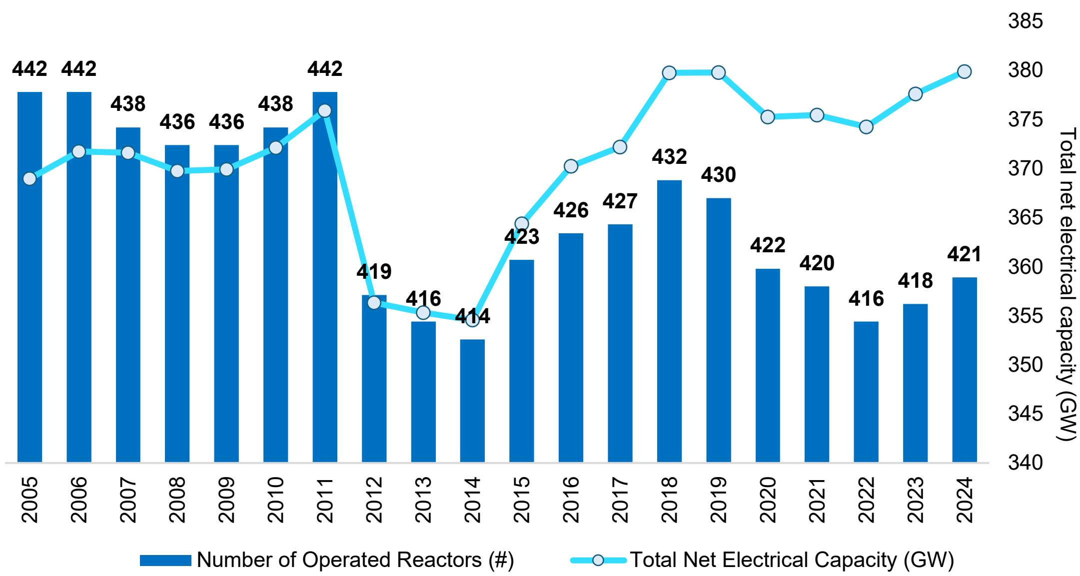
A comprehensive statistical overview of the current fleet of nuclear power stations and the pipeline of new projects is essential to the understanding of the nuclear power picture today. The IAEA Power Reactor Information System (PRIS) and the World Nuclear Association (WNA) reactor database are the two most significant sources of information, and the World Nuclear Industry Status Report (WNISR) provides additional context (International Atomic Energy Agency, 2025; World Nuclear Association, n.d.; Schneider & Froggatt, 2024).

1.2.1. Operational reactors and global capacity

As of mid-2025, it is estimated that there are 416 commercial operating reactors across 31 countries, generating a total net generating capacity of 376.3 GW (International Atomic Energy Agency, 2025). In 2023, these plants provided approximately 10% of the world's electricity (World Nuclear Association, 2025a). The figure of 416 includes 23 Long-Term-Outage (LTO) reactors, i.e. suspended reactors, of which 19 are located in Japan and 4 in India. WNISR defines a reactor as LTO if it has not produced electricity in the last calendar year and the first half of the current year. After the 2011 Fukushima Daiichi accident, much of the Japanese nuclear fleet remained in extended suspended shutdown[1]. Even though these reactors are technically viable and legally "operable", have not produced revenue and face a complex, politically sensitive restart process.

Figure 1.1:

Number of nuclear reactors and total net electrical capacity (GW) trend, 2005-2024



Source: IAEA PRIS database as of August 2025.

1.2.2. Nuclear reactors under construction

The scenario for new builds sheds light on the future of this sector. By mid-2025, there were about 62 power reactors under construction in 15 countries, representing a total future capacity of around 65.0 GW (International Atomic Energy Agency, 2025). Overall, the

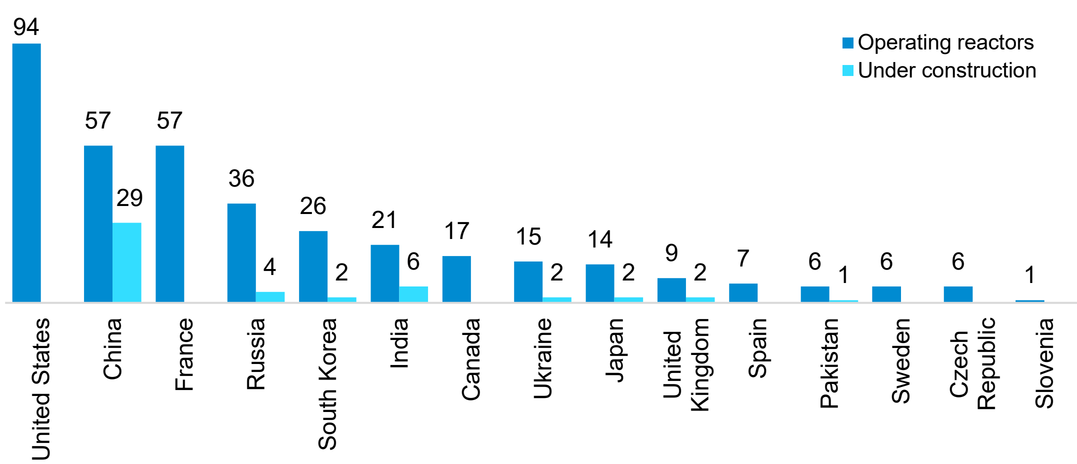
[1] In a significant recent policy shift, Japan has begun restarting its idled nuclear reactors and is now considering the development of new, next-generation replacements. The Ministry of Economy's energy plan aims to achieve 20% of Japan's grid supply from nuclear energy by 2040, more than double the 8.5% share in 2023.

geographical distribution emphasizes the overwhelming concentration of activity in Asia as the undisputed centre of global nuclear growth. Most of this growth is driven by China which has 29 reactors under construction representing 30.8 GW of future capacity, or nearly half of total global activity according to this pipeline. India has 6 reactors under construction (4.8 GW), Türkiye follows with 4 (4.5 GW) and Egypt also with 4 (4.4 GW). Other countries with active construction programs include Russia, South Korea, Bangladesh, the United Kingdom, and Brazil.

The overwhelming concentration of new build activity in China is creating a self-perpetuating ecosystem that provides a competitive advantage. By continually constructing standardized designs like the Hualong One (HPR1000), China has developed a domestic supply chain of mature suppliers, a permanently engaged and experienced construction labour force, and a steep learning curve that drives down costs and construction times. This stands in contrast to the recent experiences of many Western countries, which have recently where recent large-scale projects have often been first-of-a-kind (FOAK) projects with significant amount of delay and budget overruns as seen at the Vogtle plant in the US, and Flamanville France. This is effectively creating a two-speed world: an Eastern sphere with the Chinese and Russian (VVER) technologies, and a more commercially challenging, higher-risk Western sphere struggling to rebuild its industrial capacity.

Figure 1.2:

Number of reactors in operation and under construction, by country



Source: IAEA PRIS database as of August 2025.

1.2.3. The future pipeline: planned and proposed reactors

Beyond active construction sites, the global pipeline of future projects suggests a strong and increasing long-term interest in nuclear power. A simple distinction is made between "planned" reactors, where government approvals and funding commitments are made, and "proposed" reactors, which are at a more speculative stage.

Globally, there are roughly 107 reactors currently categorized as planned, amounting to over 100 GW of future capacity, and there are over 300 proposed reactors (World Nuclear Association, 2025b). If the projects in the pipeline are realized, this would result in a more than doubling of the current global nuclear fleet. Once again, the global outlook is dominated by projects in Asia, and China specifically, which has 39 planned and 154 proposed reactors. India has 14 planned and Russia has 23. However, there is also a healthy renewed interest outside of Asia as well. In Europe, countries such as Poland, the Czech Republic, the UK, and Sweden are advancing plans for new nuclear capacity, with even anti-nuclear countries, such as Italy and Serbia, reconsidering nuclear technology (Nuclear Energy Institute, 2025a). This wide breadth of interest demonstrates a global strategic shift to accept nuclear power as a viable resource to meet future energy and climate goals.

1.3. From Generation III+ to Generation IV reactor designs

The trajectory of civil nuclear power technology is marked by distinct generational shifts, each defined by advancements in safety, efficiency, and operational philosophy. The progression from Generation III and its enhanced successor, Generation III+, to the conceptual framework of Generation IV represents a critical inflection point in this history. This transition is not merely an incremental improvement but a fundamental divergence in approach, moving from an *evolutionary* refinement of the established Light-Water Reactor (LWR) paradigm to a *revolutionary* reimagining of the core principles of nuclear energy systems. Generation III/III+ reactors stand as the culmination of over five decades of operational experience with commercial nuclear power. Their design philosophy is a direct and deliberate response to the lessons learned from the major nuclear incidents that shaped public and regulatory perception of the industry: the partial meltdown at Three Mile Island in 1979, the catastrophic explosion at Chernobyl in 1986, and the station blackout and subsequent core meltdowns at Fukushima Daiichi in 2011. These events exposed the vulnerabilities of Generation II systems, particularly their reliance on complex, actively powered safety systems and the potential consequences of severe accidents. Consequently, Generation III+ designs are characterized by the integration of robust, often passive, safety features engineered to mitigate the consequences of such events, representing the apex of LWR technology (Cummins & Matzie, 2018; Reinberger & Haas, 2019).

In contrast, Generation IV represents a forward-looking, holistic strategy conceived to address the grand challenges of the 21st century. Spearheaded by the Generation IV International Forum (GIF), a collaborative international body established in 2001, this initiative moves beyond the singular focus on electricity generation to encompass broader goals of long-term energy security, climate change mitigation, comprehensive nuclear waste management, and enhanced economic competitiveness. The Gen IV vision is not to simply build a safer LWR, but to develop a diverse portfolio of six advanced reactor systems that employ fundamentally different coolants, neutron spectra, and fuel cycles to achieve a paradigm shift in performance (World Nuclear Association, 2024a; Generation IV International Forum, n.d.).

1.4. Small Modular Reactors (SMRs): a paradigm shift in nuclear deployment?

At the forefront of this technological wave are Small Modular Reactors (SMRs). While the small reactor concept is not new, the contemporary SMR represents a fundamental shift in the general philosophy of deploying nuclear power (International Atomic Energy Agency, 2023).

Table 1.1:
Operating SMRs

Name	Capacity	Type	Developer
CNP-300	300 MWe	PWR	SNERDI/CNNC, Pakistan & China
PHWR-220	220 MWe	PHWR	NPCIL, India
EGP-6	11 MWe	LWGR	at Bilibino, Siberia (cogen, soon to retire)
KLT-40S	35 MWe	PWR	OKBM, Russia
RITM-200	50 MWe	Integral PWR, civil marine	OKBM, Russia
HTR-PM	210 MWe	Twin HTR	INET, CNEC & Huaneng, China

Source: World Nuclear Association (2025d).

1.4.1. Definition and features

The IAEA define SMRs as advanced reactors with a power output generally up to 300 MWe per unit, designed for modular construction and factory fabrication (International Atomic Energy Agency, 2023). Their key characteristics include: (i) modularity and factory-fabrication; (ii) enhanced passive safety; and (iii) siting flexibility. In particular, major components, or entire reactor module, are made in a controlled factory environment and shipped to the site for assembly. This is to improve quality, decrease construction schedules, and reduce the labour associated with site construction (U.S. Department of Energy, n.d.). Concerning safety instead, SMR designs are heavily relying on passive safety systems relying on natural forces such as gravity, natural circulation, and convection to cool the reactor and for emergency shutdown of the reactor. This generally decreases the reliance on the active components (pumps for instance) and external power. which can theoretically increase the margin of safety, and in some designs significantly reduce core melt accidents (European Commission, n.d.; International Atomic Energy Agency, 2023; OECD Nuclear Energy Agency, 2021). Site flexibility refers to their smaller size and smaller emergency planning zones (EPZs) and, therefore, less need for cooling water allow SMRs to be sited in more places where large plants could not be sited (U.S. Department of Energy, n.d.).

1.4.2. The economic premise and its challenges

The central economic argument for SMRs is that it will shift from the *economies of scale* in similar large reactors to e*conomies of volume*. In principle, the higher capital cost per-kilowatt for small reactors can be overcome by the cost reductions achieved through mass production of standardized modules in a factory setting. However, the business case is based on a commercially unproven hypothesis. The learning effects and cost savings from factory produced modular construction cannot be realized until multiple units have been ordered and manufactured. However, the first-of-a-kind (FOAK) and first few series units will be priced at greatly elevated costs compared to traditional alternatives, making it hard to obtain first orders to start those years necessary to achieve the learning effects (GLOBSEC, 2025). This economic "valley of death" represents the main barrier to the successful deployment of SMRs, and explains why, despite having over 80 designs, only a few prototypes are operating mainly in China and Russia (International Atomic Energy Agency, 2022).

Moreover, SMR economic viability depends on solving two parallel challenges. First, the model of global factory production requires a significant, qualified, and resilient international supply chain, which has atrophied in the West and is a known bottleneck. Second, although there are significant benefits with a standardized design, if the national regulator in each country decides to require a lengthy and elaborate licensing review the overall regime becomes economically unviable. International regulatory harmonisation of process will be a prerequisite if the SMR business model is to succeed. Recognising this, international organisations such as IAEA with its Nuclear Harmonization and Standardization Initiative (NHSI) and the OECD-NEA with its SMR Regulators' Forum are developing processes to enable collaborative licensing and acceptance of common standards (International Atomic Energy Agency, 2024a; Office for Nuclear Regulation, 2025).

1.4.3. Applications beyond the grid

An advantage of many SMR designs is to perform several non-electric applications. Many advanced SMRs are designed to produce high-temperature heat for industrial processes, whether it is for chemical production, sewage processing, low-carbon hydrogen generation, or even for desalination processes. This ability to not only generate multiple revenue streams will serve to further establish SMRs as a viable option, but it also permits SMRs to decarbonise hard-to-abate sectors which extend beyond electricity generation (Nuclear Energy Institute, n.d.; European Commission, n.d.).

1.4.4. Microreactors

Microreactors are a smaller subset of SMRs, where the power plants typically have a generating capacity of 1 to 10 MWe (Nuclear Energy Institute, 2025). Microreactors are designed not to compete with grid-scale power but instead to serve smaller niche, off-grid markets, including remote industrial sites like mines, isolated communities, or forward-operating military bases that currently rely on expensive, logistically challenging, and carbon-intensive diesel generators (Lovering, 2023). Key characteristics include portability (transport by truck or by plane) and typically long operational periods (up to 10 years) without refuelling (International Atomic Energy Agency, 2023).

1.5. Generation IV reactors

Generation IV (Gen IV) represents a portfolio of advanced reactor technologies being developed for future commercial deployment, likely after 2030. These designs are being developed by the Generation IV International Forum (GIF 14 countries), with an emphasis or priority on four main goals: sustainability (e.g., waste reduction, maximize fuel utilization), economics, safety and reliability, and proliferation resistance (Generation IV International Forum, n.d.).

The use of the term "Generation IV" is more a reference to an organizational structure aligned with 21st century priorities than a technological trajectory. The majority of these concepts were first evaluated in the 1950s and 1960s (molten salts, sodium cooled reactors, etc.) but were largely shelved in favour of the now-dominant Light Water Reactor (LWR) technology. As modern day challenges arose, particularly related to the long term management of nuclear wastes, and the reduced efficiency of uranium resource utilization, these Gen IV types emerged from their slumber and are now being researched and evaluated. This explains the relatively low technology readiness level (TRL) of Gen IV types compared to SMRs which are based on developed LWR technology.

According to the Generation IV International Forum, the six primary Gen IV systems are:

1. **Very-High-Temperature Reactor (VHTR):** A helium-cooled, graphite-moderated reactor operating at over 900 °C, suitable for highly efficient electricity generation and hydrogen production, with major research led by the Generation IV International Forum and prototypes pursued in South Korea through KAERI's NHDD project and in China with the HTR-PM demonstration at Shidaowan.
2. **Sodium-Cooled Fast Reactor (SFR):** A fast-neutron reactor cooled by liquid sodium, capable of breeding its own fuel and burning long-lived actinide waste from conventional reactors, exemplified by TerraPower's Natrium project in Wyoming, USA, supported by the U.S. Department of Energy, and by Russia's BN-800 reactor at Beloyarsk, one of the world's only operating SFRs.
3. **Lead-Cooled Fast Reactor (LFR):** A reactor concept similar to the SFR but using molten lead as coolant for enhanced safety, currently being advanced by Newcleo across the UK, Italy, and France, by Ansaldo Nucleare through the ALFRED demonstrator planned in Romania, and by the Eagles Consortium in Europe, which includes partners such as SCK-CEN, ENEA, and RATEN.
4. **Gas-Cooled Fast Reactor (GFR):** A reactor that combines the features of a fast reactor with a high-temperature helium coolant, with development focused on the ALLEGRO demonstrator led by central European countries under ESNII, as well as

commercial concepts from General Atomics in the United States and the HeFASTo design in the Czech Republic.

5. **Molten Salt Reactor (MSR):** A design that uses molten fluoride or chloride salts either as the coolant or as a medium in which nuclear fuel is dissolved, offering unique safety and fuel cycle benefits, currently being developed by Kairos Power in Tennessee with its Hermes-2 reactor, by Natura Resources and Abilene Christian University with the MSR-1 test reactor in Texas, and by companies such as Terrestrial Energy and Moltex in Canada and Europe.
6. **Supercritical-Water-Cooled Reactor (SCWR):** A reactor that uses water at very high pressure and temperature in a supercritical state to achieve exceptional thermal efficiency, with active R&D programs at the University of Tokyo and JAEA in Japan, in Canadian research institutes working with CANDU Energy, and within international collaborations coordinated through the Generation IV International Forum.

Table 1.2 provides a comparative overview of these advanced reactor technologies.

Table 1.2:

Comparative analysis of advanced reactor technologies

Technology Type	Power Range (MWe)	Coolant	Neutron Spectrum	Primary Mission/Goal	Key Advantages	Key Challenges	Development Status
LWR-SMR	50 – 300	Water	Thermal	Grid electricity, process heat, repowering coal plants	Near-term deployability, established supply chain, regulatory familiarity	High FOAK costs, economies of scale disadvantage	Commercial (Russia); Under construction (China); Licensing/early construction (US, Canada)
Microreactor	1 – 20 (some up to 50)	Gas, Liquid Metal, Molten Salt	Thermal/Fast	Off-grid power for remote sites, military bases	Portability, long-life core, replaces diesel	High cost per MWe, niche market	Demonstration, Licensing
VHTR	~100 – 300	Helium	Thermal	High-temp process heat, hydrogen production, electricity	High efficiency, inherent safety (TRISO fuel)	Materials for high temperature, fuel qualification	Commercial operation (China, HTR-PM)
MSR	Varies	Molten Salt	Thermal/Fast	Waste burning, thorium fuel cycle, process heat	Inherent safety (low pressure), fuel cycle flexibility	Materials corrosion, complex fuel chemistry	R&D, Prototyping; China's TMSR-LF1 prototype operating
SFR	50 – 1500	Sodium	Fast	Fuel breeding, waste transmutation	Resource sustainability, passive safety features	Sodium–water reactivity, proliferation concerns	Commercial (Russia, BN-800); Demonstration/Commissioning (India, PFBR)
LFR	50 – 1200	Lead	Fast	Fuel breeding, waste transmutation, "battery" concept	Enhanced safety (chemically inert coolant)	Materials corrosion, coolant solidification	R&D and prototyping; FOAK BREST-OD-300 under construction (Russia)

Source: Synthesized from IAEA (2023), WNA (2024), NEI (2025), and GIF (2025).

1.6. Key drivers and trends shaping the nuclear sector

The renewed momentum behind nuclear energy is not an isolated development, but is contingent upon multiple significant, converging macro-drivers. All of these drivers are significantly rewriting the strategic, political, economic value-case for nuclear energy development around the world.

1.6.1. The COP28 inflection point

The most notable driver is the global effort to tackle climate change. As countries grapple with the challenge of reaching increasingly ambitious carbon-neutral targets, they are realizing that intermittent renewables alone will not reliably power a modern, industrialized economy indefinitely[2]. To achieve a stable, net-zero energy system, the nuclear energy innovation ecosystem, providing huge loads of dispatchable, 24/7 carbon free electricity, plays an increasingly necessary part (World Nuclear Association, 2025a).

This transition in thinking had a fundamental moment at the 2023 UN Climate Change Conference (COP28) held in Dubai. For the first time in the history of the COP process, the final Global Stocktake agreement explicitly recognized accelerating nuclear energy as one of the key solutions for achieving "deep, rapid and sustained reductions in greenhouse gas emissions" (World Nuclear Association, 2023b). This was accompanied by a landmark ministerial declaration, led by the United States, France, and the UK, in which over 20 countries pledged to work together to triple global nuclear energy capacity by 2050. While this is not legally binding, it is aspirational, and influential in terms of its strategic importance. This serves as a very powerful political and financial de-risking signal to the international market. Supporting nuclear energy at the highest levels of international climate diplomacy, gives long-term policy certainty to private sector investors who require long-

[2] The primary challenge of Renewable Energy Sources (RES) like wind and solar is their inherent intermittency and resulting lack of dispatchability, i.e. the inability to generate power on demand. This issue is particularly acute in residential and commercial grids where electricity demand often peaks in the evening, precisely when solar generation falls to zero. This daily supply-demand mismatch, often illustrated by the "duck curve" problem, creates significant challenges in maintaining the real-time balance necessary for grid stability. While mitigation strategies such as large-scale energy storage exist, they incur substantial system costs for balancing and backup.

term, capital intensive, multi-decade projects. Moreover, the declaration called on shareholders of the World Bank and International Financial Institutions (IFIs) to include nuclear in their lending policies. The goal is to facilitate access to vast new sources of capital from institutions that have historically been unwilling to finance nuclear projects, with the aim to potentially lower the cost of capital and create new funding streams.

1.6.2. Energy security and geopolitical realignment

Parallel to the climate driver, concerns over energy security have returned to the forefront of national policy, particularly in Europe following the disruption of Russian gas supplies in the context of the Russian invasion of Ukraine in March 2022. Nuclear power relies on a dense and easily storable fuel (uranium) sourced from a more diverse set of global suppliers, and hence is seen as a tool for enhancing national energy independence and protecting economies from volatile fossil fuel markets (World Nuclear Association, 2025a; i-energy, n.d.).

But energy security and nuclear power generation are occurring alongside an evolving nuclear map. By 2030, China is on track to become the world’s largest nuclear power generator as they leverage their massive domestic build-out to create a powerful export platform (Clifford, 2025). In the meantime, Russia’s state-owned Rosatom remains the world's top provider of new reactors, allowing Moscow to exert geopolitical leverage over its client states. The West is responding competitively: the United States is enacting legislation such as the ADVANCE Act to push for expedited regulations and the deployment of their own advanced reactor technology (Morgan Lewis, 2025), and in Europe, countries are reviving nuclear programs and their previous phase-out policies (Nuclear Energy Institute, 2025a) to restart their industrial base and achieve technological sovereignty.

1.6.3. Economic and financial evolution: new models for a new era

While there is substantial political and strategic tailwinds to expand nuclear energy, the economic challenges persist as the single greatest barrier to nuclear expansion. Upfront capital costs, long lead-times for construction, and risk of delays and cost overruns associated with large-scale nuclear energy development has made financing large-scale nuclear energy projects enormously challenging, especially for private investors (International Energy Agency, 2025). This is why governments have begun laying out new policies and new funding initiatives aimed at reducing risk. For example, in the US, the Inflation Reduction Act, including extensive production tax credits on both existing and new nuclear plants (Callan Institute, 2025). In the UK, the government has introduced the Regulated Asset Base (RAB) model which allows developers to earn a return during the construction phase, shifting some of the financial risk to consumers but making projects more attractive to investors (Bird & Bird, 2025).

Perhaps the greatest economic change, however, is the emergence of an entirely new class of customer: the technology sector. The exponential growth in the demand for data centres and artificial intelligence (AI) is creating an unprecedented need for massive amounts of reliable, 24/7, carbon-free electricity, a power profile that is typically provided by nuclear energy (Callan Institute, 2025). Major technology companies like Microsoft, Google, and Amazon are actively looking to procure nuclear power, establishing long-term Power Purchase Agreements (PPAs), and where possible, making direct investments in new nuclear projects[3]. A long-term PPA from a credit-worthy corporate offtaker is a highly bankable asset, and is able to secure project-debt and attract private equity. This reveals a potentially new, commercially-viable financing path for SMRs that is not so reliant on traditional state and utility-based funding. If SMRs are indeed financed in this way, this would be a revolutionary moment for the nuclear industry.

1.7. Conclusion: setting the stage for financial feasibility analysis

This chapter shows that nuclear energy is in a new era where an ideal convergence of technological ability, political will, and market demand has come together. The global push toward decarbonization, driven home by the commitments made at COP28, has firmly reset

[3] Amazon Web Services acquired in 2023 a data center campus for $650 million that is directly powered by Talen Energy's 2.5 GW Susquehanna nuclear plant in Pennsylvania. Microsoft has a power agreement with Constellation Energy to help power a Virginia data center with nuclear energy, targeting hourly carbon-free matching, and is exploring SMRs for future AI workloads. Google works in partnership with utility Southern Company to procure 24/7 carbon-free energy, including output from the Vogtle nuclear plant, for its data centers in Georgia.

nuclear power back to where it belongs, as an obligatory solution for a sustainable energy future. The geopolitical concerns for energy security, combined with a massive demand for new electricity from the digital economy, are also bringing more powerful tailwinds. Technologically, an entirely new generation of advanced reactors, especially with the potential for flexible, factory-built nuclear small modular reactors (SMRs), offers paths forward to address many of the challenges that have constrained this industry in the past.

Moreover, this chapter also makes clear that it is absolutely fundamental to effectively address financial barriers in order to unlock the technology intrinsic full potential over the next decades. The first-of-a-kind costs for new designs, the multi-decade investment timeframes, the complexity of rebuilding a used-up supply chain, and the need for coherent regulatory regimes create types of risk that characterize a risk profile that is difficult for traditional financial tools to support. The success of the nuclear renaissance, and specifically that of SMRs, is therefore not merely an engineering question: it is, fundamentally, a financial one.

This is precisely the challenge that motivates the research presented in this thesis. A nuanced understanding of the investment case for SMRs and nuclear reactors in general, requires a probabilistic approach that can model the interdependence between technology costs, public policy incentivization, market dynamics, and project execution risk. Thus, by setting up the highly technical and strategic environment of current nuclear, this chapter has created the pathway for the core analysis to follow. A detailed account of the financial viability of SMRs using robust quantitative analysis that will serve as a tool for decision makers as they navigate their way to a new era of nuclear energy.

2. Nuclear Power Plant Financing and Bankability

The financing of new nuclear power plants (NPPs) is a central and complicated policy issue facing governments around the world as they grapple with the trilemma of the decarbonisation, energy security, and industrial development. The academic and policy literature frames a core paradox: the enormous public policy benefit of nuclear power to provide large amounts of reliable, low-carbon baseload electricity on the one hand, versus its economic unprofitability as a source of private capital under conventional market conditions (Wealer et al., 2021). The chapter argues that nuclear financing historically went from pure state control to state-facilitated risk mitigation frameworks that simply support private sector investment saturation with the primary goal of making projects "bankable". Here, bankable does not only mean profitable, but it refers to the successful and comprehensive allocation of a project's overwhelming risks away from private financiers and onto other entities, principally consumers and taxpayers.

This review will start by establishing the fundamental economic and financial profile of nuclear investments that give rise to their challenges of financing. The discussion will then provide a typology of the financial risks facing partakers of individual projects in contrast to collective risks across an investors and lenders perspective, introducing the notion of bankability. We will then systematically review, from a regulated market perspective, traditional financial structures that have been used, and the current, innovative, and contemporary structures that have emerged in liberalised and transitional markets.

2.1. Fundamentals of project finance for nuclear investments

2.1.1. Debt and equity financing

The financing of any large infrastructure asset, in particular, for a new nuclear power plant (NPP), will typically constitute a combination of two broad classes of capital: equity, and debt. The ability to distinguish between the characteristics of these two classes is the first step to understanding the financial architecture of a project's financing.

Equity is the risk capital that the owners/shareholders provide to the NPP. Equity capital providers bear the higher level of risk, since any claim on the project company's assets or cash flows are subordinate to those of all other creditors, typically, debtholders. In a liquidation event, equity investors would be paid last. In other words, they are entitled to the residual value remaining from the sale of all the project assets. The compensation for this high-risk position is the potential for commensurate returns, realised through a share in the project's residual profits (paid as dividends) and the potential for capital appreciation of their stake.

Debt, instead, is borrowed capital that must be paid back on a specified schedule with agreed payments on principal and interest repayments. Debt has, as said before, higher seniority than equity. Therefore, being a creditor puts you as a higher class of claims to the project's cash flow and in case any loss occur, with greater entitlement to the project's assets. The seniority of the debt makes it by definition, less risky than equity, which translates into the cost debt financing being lower than the cost of equity financing.

2.1.2. The debt-to-equity ratio and the cost of capital

The structural decision regarding the proportion of debt and equity allocated to funding a project (the debt to equity ratio, or gearing), is fundamental and has considerable implications for its economic viability. The cost of these different forms of financing, known as the Weighted Average Cost of Capital (WACC), represents the total cost of financing the project, and is the main measure of a project's financing cost. The WACC is calculated as:

$$WACC = kE \ x \ \left(\frac{Equity}{Debt + Equity}\right) + kD \ x \ \left(\frac{Debt}{Debt + Equity}\right) x \ (1 - t)$$

where Equity / (Debt + Equity) is the proportion of equity, kE is the cost of equity, Debt / (Debt + Equity) is the proportion of debt, kD is the cost of debt, and t is the corporate tax rate.

Given that the cost of debt (kD) will be less than the cost of equity (kE) with all things being equal, a financial structure that contains greater levels of debt (i.e., higher leverage), should result in a lower WACC. The lower WACC means the project will be more economically competitive, and may translate into a lower required price for the electricity it generates, which is important for regulators and off-takes (International Atomic Energy Agency, 2017). Projects that have successfully attracted financing, both before and since commercial nuclear power was widespread, had debt-to-equity ratios in the range of 60:40 to 70:30, considerably lower than leverage ratios seen in other large infrastructure sectors (International Atomic Energy Agency, 2017). This evident conservatism in leverage is not merely a preference, but is a constraint imposed by the market that reflects the nuclear risk reality. The various unique, long-tail risks associated with nuclear power (construction, policy, and decommissioning, all of which are different to financing) make any commercial lender not be willing to take any significant exposure until there is substantial equity cushion to transfer risks onto, to make the project bankable. The financing of all NPPs on a project finance basis demonstrates this point. It suggests that the risks remaining, after the equity cushion is exhausted, are too great for a commercial lender to justify without the backing of a large, credible equity provider, typically a sovereign or state-backed corporate entity (International Atomic Energy Agency, 2017). The low levels of leverage therefore represent a direct consequence of the nature of nuclear risk.

2.1.3. The centrality of project cash flows and the "Waterfall"

A fundamental metric in any project finance analysis is the Cash Flow Available for Debt Service (CFADS), defined as the total amount of cash flow an asset could potentially use to pay interest on its debt and repay debt principal in the period, and it's used in the debt sizing and sculpting[4] and equity returns calculations.

$$CFADS = EBITDA - Cash\,Taxes \,^{+}/- \,\Delta NWC - Maintenance\ Capex$$

With:

- EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization
- Cash Taxes: amount of taxes paid considering the effect of interest expenses[5]
- ΔNWC: Change in Net Working Capital
- Maintenance Capex: Capital expenditures undertaken to sustain historical revenue and profitability, i.e., excludes "growth capex"

CFADS represents the only source of funds available to fund all financial stakeholders. Therefore the amount, timing, and predictability of CFADS are the primary focus of every due diligence effort that lenders and investors with capital intend to perform. There is a strong and direct relationship between a project's contractual structure and the predictability of its CFADS. A project with a long-term fixed-priced electricity off-take contract and contracts to pass-through volatility in variable costs such as fuel will produce predictable and stable CFADS. Such structures are much more attractive to lenders that are risk averse than the project following small market electricity prices, where the CFADS's uncertainty is much riskier (International Atomic Energy Agency, 2017).

The idea of the "cash flow waterfall" is a helpful analogy to demonstrate the strict order of payments in a project finance structure and reinforces the concept of debt seniority. In any operational period, the project's CFADS is paid according a previously agreed and contractually binding sequence: (1) first, to pay the scheduled payment of interest and principal repayments on the projects senior debt; (2) second, if there is any remaining cash after senior debt payments, service to any subordinated debt; (3) third, if there is cash left

[4] In project finance, *debt sizing* is the process of determining the total amount of debt a project can borrow, while *debt sculpting* is the process of structuring the repayment schedule of that debt to match the project's fluctuating cash flows.
[5] This is a key difference from the calculation of the unlevered free cash flow, which does not consider interest expenses to calculate taxes (so-called "unlevered taxes").

after paying both senior and subordinated debt service, it is considered residual profit and is available for dividends to equity shareholders.

2.2. The economic and financial profile of a nuclear power investment

In a nutshell, a nuclear power plant is expensive to build, and cheap to run. The literature is unequivocal in stating that the unique and challenging economic characteristics of new NPPs are the root cause of their financing challenges. These projects are characterised by immense scale, capital intensity, and a large importance of the project's cost of capital on the overall economic viability.

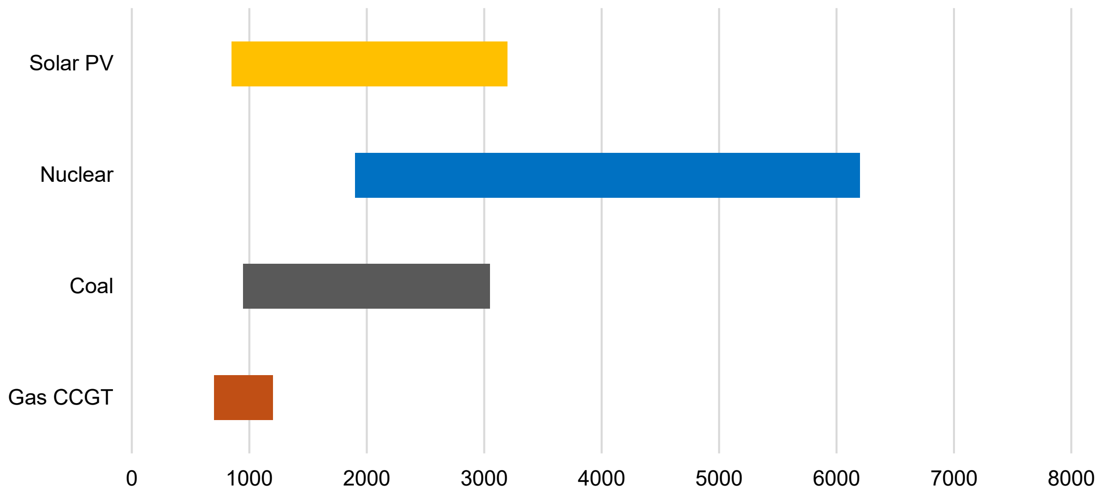
2.2.1. Capital intensity, scale, and construction lead times

NPPs have been identified in the literature as one of the most capital-intensive energy infrastructure projects[6] (OECD Nuclear Energy Agency & International Energy Agency, 2009; World Nuclear Association, 2024). The initial investment a of nuclear power plant is defined Overnight Construction Cost (OCC), which comprehends the Engineering, Procurement, and Construction (EPC), or owners costs (such as land acquisition and licensing) and contingency costs, but excludes financing costs (Wealer et al., 2021; Barkatullah and Ahmad, 2017). OCC estimates for modern Generation III/III+ reactors in Western Europe or North America are typically in the range of $5,000 to $11,000 per kilowatt (Wealer et al., 2021; Barkatullah and Ahmad, 2017).

[6] In general, a project is defined *capital intensive* when has an high ratio of fixed costs over variable costs.

Figure 2.1:

Overnight capital cost range, by technology ($/KWe)



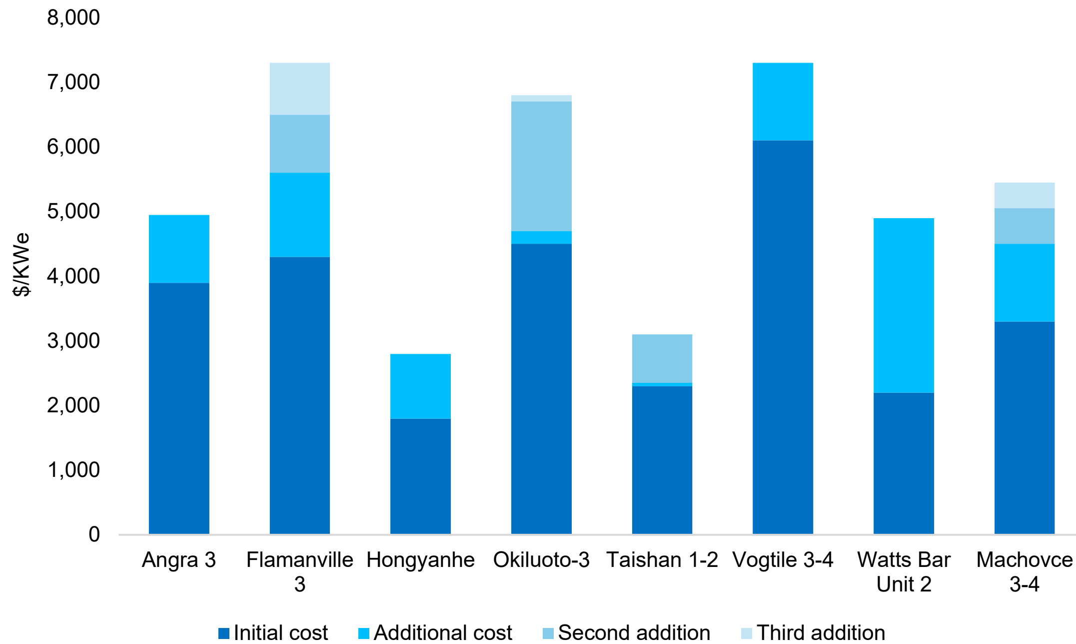
Source: IEA & OECD Nuclear Energy Agency (2015), Projected cost of generating electricity.

A recurring theme in the literature is cost escalation, especially when we look at Western nuclear projects. Wealer et al. (2021) present a review of the escalation evidence of recent European and American projects. The Olkiluoto-3 project in Finland for instance was originally estimated at approximately €3.2 billion, finally costing around €11 billion. In France, the Flamanville-3 project escalated from around €3.3 billion to over €10.5 billion, whereas the Vogtle units in the USA escalated their originally intended $14 billion, to more than $30 billion.

On top of the high capital costs, construction lead times are also very long, with initial projected construction periods between five and ten years inflating up to fifteen years (Wealer et al., 2021; Barkatullah and Ahmad, 2017; International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). This translates in higher periods incurred without revenue generations, critically multiplying the project's associated financial risk.

Figure 2.2:

Revised investments cost estimates ($/KWe)



Source: Barkatullah and Ahmad (2017).

2.2.2. Levelized Cost of Electricity (LCOE)

A key finding in the economic literature is the final levelized cost of electricity (LCOE) associated with a new NPP is much more sensitive to the cost of capital than any other variable, including fuel or operating costs (OECD Nuclear Energy Agency & International Energy Agency, 2009; International Atomic Energy Agency, 2017). This sensitivity is a function of the capital intensity and long construction periods associated with NPP projects. Interest During Construction (IDC) is the largest component of financing costs, as it represents the accumulation of interest on debt and the return on equity required for the non-revenue generating phase. The International Atomic Energy Agency (2017) observed that IDC can compound into very large amounts, and is exponential with respect to construction period and interest rate. Wealer et al. (2021), through a Monte Carlo simulation, found that for a 15-year construction period IDC would represent greater than 40% of Total

Construction Cost (TCC), which is substantially greater than the 30% estimated in earlier studies (Tolley et al., 2004).

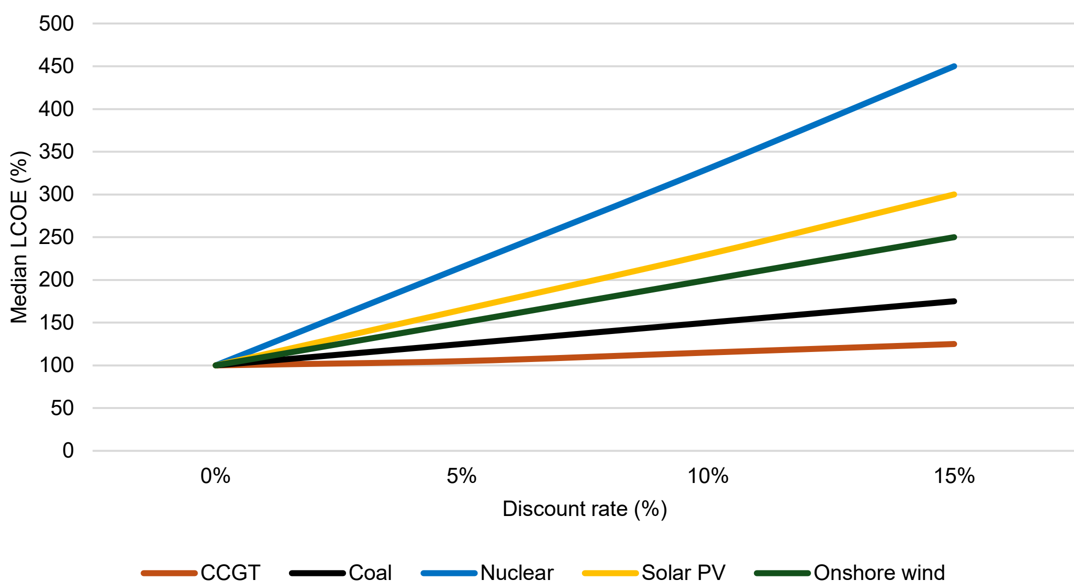
The same paper from Wealer et al (2021) simulates the economic performance of a generic Gen III/III+ reactor under a range of plausible WACC assumptions (4% to 10%). The bottom line is crystal clear: the expected Net Present Value (NPV) of such an investment is negative, with mean losses ranging from approx. -$4.8 billion to -$10 billion. This supports the claim that from the point of view of a private investor in a competitive market, a new nuclear power plant will not yield an attractive business case without significant external support mechanisms to bring down WACC or guarantee revenue.

The literature indicates a fundamental paradox that has stagnated the new build of nuclear in many western countries. By introducing advanced, "First-of-a-Kind" ("FOAK") reactors, presumably to increase efficiency and safety, they are also introducing such tremendous construction uncertainty that it is nearly un-financeable without significant state mechanisms to reduce the uncertainty. This situation leads to a debilitating negative feedback loop. The literature states FOAK designs can add 30-35% to the overnight cost (Tolley et al., 2004; Barkatullah and Ahmad, 2017). Construction risk remains the number one deterrent for private lenders and equity investors, because when they perceive increasing uncertainty, they also increase their internal hurdle rates. A higher internal hurdle results in a higher WACC. As discussed in the above, higher WACC combined with long construction times leads NPV deeply into negative territory to the point it is economically uncompetitive. Consequently, the attempt to innovate perversely leads to a financial profile so risky that it prevents the very activity, continuous construction, needed to gain experience, standardise processes, and ultimately reduce the risk and cost of future projects.

LCOE is a measure of the cost efficiency of different electricity generation methods. It is the average revenue per unit of electricity produced, which is needed to recover the costs of building and operating a power plant over its planned lifetime (World Nuclear Association, 2023a). Nuclear power's LCOE is greatly affected by the capital costs. Where capital costs are controlled, nuclear power can provide a competitive source of low-carbon electricity (World Nuclear Association, 2023a). For example, for advanced nuclear power, the LCOE was approximately $110/MWh in 2023, and it is expected to stay at the same approximate level until 2050. Compared to other energy sources, the LCOE for nuclear power is on the high side compared to onshore wind and utility-scale solar PV in many regions, especially with the continued decline in renewable costs (Lazard, 2025). However, LCOE does not include system costs[7], which will need to consider costs of balancing, backup, and grid extensions for intermittent renewables. These costs are not fully captured in LCOE comparisons, meaning the total cost of a system that has a high penetration of renewables may be greater than useful LCOE metrics suggest (World Nuclear Association, 2023a).

Figure 2.3:

Effect of discount rate on levelized cost of electricity (LCOE) for different technologies



Source: World Nuclear Association (2023a).

Nuclear power can provide reliable, dispatchable, low-carbon baseload power, which has important system benefits for grid stability (International Energy Agency, 2022). Lifetime extensions till the end of life for existing nuclear power plants offer the most plausible least-

[7] System costs include expenses related to grid reinforcement, ancillary services (e.g., frequency regulation), and the cost of backup generation required to ensure reliability when intermittent sources like wind and solar are unavailable. These costs become increasingly significant at high levels of renewable penetration.

cost low-carbon generation option. Nuclear power will need to have reduced construction costs and project schedule in order for new nuclear projects to be competitive in markets with cost competitive renewables (International Energy Agency, 2022).

2.3. Financial risks and the question of bankability

Nuclear projects are subject to a rigid framework of risk analysis by financial institutions. The term "bankability" is derived from that analysis, and relates not to the profitability of the project, but to whether it is structured in an appetible way to lenders.

2.3.1. Defining and categorising nuclear project risks

The body of literature provides very thorough frameworks for identifying and categorising the different risks of a NPP project, with the detailed risk registers of the International Atomic Energy Agency (2017) and OECD Nuclear Energy Agency & International Energy Agency (2009) being particularly helpful. All of the risks can be grouped into the following topical areas:

Construction and Completion Risk

This is arguably the single largest and most immediate risk for financiers. It includes potential substantial cost increases, timeline delays, disruption of the supply chain, and the ultimate failure of the plant to achieve its design performance and capacity upon commercial completion (International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009).

Market Risk

This risk is primarily associated with the volatility of wholesale electricity prices in liberalised markets. Given the long operational life of a NPP (+60 years), the risk represents decades of revenue uncertainty. Recently, this risk has been exacerbated by the massive deployment of variable renewable energy sources (VRES), whose zero-marginal-cost generation can depress wholesale prices for extended periods of time, effectively making impossible for any capital intensive asset such as a NPP to recover its fixed costs (International Atomic Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009).

Political and Regulatory Risk

This category of risk includes risks like the adverse change of government policies such as a nuclear phaseout plan (Germany post-Fukushima), as well as risks like significant delays in licensing; new undesirable and expensive safety requirements imposed during construction or operations, and changes in taxation (International Atomic Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009).

Long-Term Liability Risk

This risk is associated with uncertainty in the final costs of decommissioning the plant and permanent disposal of spent nuclear fuels. While the plant is in operation, fee revenues are collected, but the ultimate costs are far in the future and carry significant uncertainty creating a long-tail liability for investors (OECD Nuclear Energy Agency & International Energy Agency, 2009). Table 2.1 provides a summary of these key financial risks and the principal mitigation strategies discussed in the literature.

Table 2.1:

Key financial risks in nuclear new build projects and associated mitigation strategies

Risk Category	Description of Risk	Primary Mitigation Mechanism(s) in Literature	Party to Whom Risk is Transferred
Construction Cost Overrun & Schedule Delay	The risk that the project will cost more and take longer to build than forecast, destroying project economics.	Turnkey EPC Contracts (rare); Government Loan Guarantees; Regulated Asset Base (RAB) Revenue Stream; Phased financing for SMRs.	EPC Contractor (limited); Government/Taxpayer; Consumers.
Electricity Price Volatility	The risk that wholesale electricity prices will be too low to cover the plant's fixed costs and debt service over its lifetime.	Contract for Difference (CfD) Strike Price; Long-term Power Purchase Agreement (PPA); Regulated Tariffs; Mankala model (at-cost supply).	Government/Consumers; PPA Off-taker; Shareholders (in cooperative model).
Political & Regulatory Change	Risk of a change in law, licensing delays, or a politically-motivated shutdown preventing the plant from operating or recovering costs.	Political Risk Insurance (from ECAs); Government Support Agreements (e.g., compensation for political shutdown).	Insurers/ECAs; Government/Taxpayer.
Long-Term Liabilities	The risk that funds set aside for decommissioning and waste disposal will be insufficient to cover the final costs.	Decommissioning Fund Legislation; National Waste Management Policy	Government/Taxpayer (as ultimate guarantor); Consumers (via levies).

2.3.2. The lender's perspective and the principle of risk allocation

From the perspective of debt providers, a project becomes bankable when risks have been sufficiently mitigated and transferred away from the project entity such that the remaining cash flows are sufficiently predictable and capable to provide a high degree of certainty in the service of debt. Lenders are inherently risk-averse, their upside is the repayment of principal plus interest, while their downside is the complete loss of their capital.

There is a central principle in the project finance literature: risk should be allocated to the party best suited to bear it (International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). For example, a construction contractor is best suited to manage on-site productivity. However, the literature consistently states that for the biggest nuclear risks (extreme cost overruns, major regulatory changes or negative long-term market price collapse), no single commercial party can credibly manage the risk or have a balance sheet large enough to absorb it (International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009; Weibezahn and Steigerwald, 2024). This structural reality validates the role of the government as the ultimate risk-absorber. Thus, for a nuclear project to be bankable, the two biggest risks, construction and market price risk must be minimized from the project balance sheet by transferring risk to another entity, contractors (to a limited extent), consumers, and/or taxpayers (Weibezahn and Steigerwald, 2024).

2.3.3. Key liquidity and coverage metrics

Lenders use a set of quantitative tools to conduct the bankability test, to determine whether the project is capable of generating enough cash to amortize the debt incurred during the life of the loan.

Debt Service Cover Ratio (DSCR)

The DSCR is a consolidated, period-by-period measurement of the project's cash flow cushion, and can be calculated as:

$$DSCR = \frac{CFADS}{Debt\ Service}$$

With:

- CFADS: Cash Flow Available for Debt Service in a specific
- Debt Service: includes both interest expenses and principal repayments over same the period

A DSCR of 1.0x means that the project has generated just enough cash in a period to cover its debt payments, but lenders want some wiggle room above this for unexpected underperformance. Lenders will tend to set minimum DSCR running between 1.3x to 1.6x for each period during the term of the loan before deeming the project bankable (International Atomic Energy Agency, 2017).

Loan Life Cover Ratio (LLCR) & Project Life Cover Ratio (PLCR)

These are look-ahead metrics which assess the project's ability to repay loans over the long run. The LLCR is calculated as the NPV of all future CFADS over the remaining life of the loan divided by the current loan balance, while the PLCR takes future CFADS over the entire remaining life of the project. These ratios provide enough comfort to lenders that, even if the project experiences a temporary bump-in-the-road, the total future cash flows are sufficient to repay the full loan. Lenders set typical minimum thresholds running between 2.0x to 2.5x for LLCR (International Atomic Energy Agency, 2017).

The following table provides concrete benchmarks for these and other metrics used in the credit assessment of power projects, illustrating the specific quantitative thresholds that define bankability.

Table 2.2:

Lender creditworthiness metrics for power projects

Metric	Project Finance Criteria	Bank-Market Corporate Debt Criteria	Investment Grade Generator Criteria	Sub-Investment Grade Generator Criteria
DSCR	1.3X–1.6X			
LLCR	2.0X–2.5X			
PLCR	3X			
Debt/Equity	70/75–25/30			
Pre-tax interest coverage		3.0X–5.0X	3.0X–6.0X	2.0X–3.5X
FFO interest cover			3.5X–8.0X	2.5X–4.0X
FFO to debt			20%–45%	10%–20%

Source: International Atomic Energy Agency (2017).

2.4. Traditional financing methodologies in regulated markets

The historical context of nuclear financing is based on regulated market frameworks, which offered the stability and certainty needed for such long-term, capital-intensive investments. These traditional models sufficiently mitigated the major risks that today exist in liberalised markets.

2.4.1. The sovereign model: Government and State-owned enterprise financing

The sovereign model represents a foundational financing structure from the first wave of nuclear expansion; i.e., the model corresponds to the direct funding of an NPP by a government budget, or more typically, by a utility owned by the state which benefits from an implicit or explicit sovereign guarantee (Barkatullah and Ahmad, 2017; International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). In a sovereign model all the risks associated with the project, including construction risk, operational risk, market risk, or long-term liability risk are born by the state (and ultimately taxpayers). The sovereign model provides the project with the lowest possible cost of capital, as the financing is backed by the full faith and credit of the government, which can raise funds at the sovereign borrowing rate (International Atomic Energy Agency, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). Today the sovereign model is still the model of choice in countries with state-led industrial policies like China and Russia, and is the foundation for their nuclear export projects, which often involve government-to-government loans (Wealer et al., 2021; Barkatullah and Ahmad, 2017).

2.4.2. Corporate finance: the role of large, creditworthy utilities

In many Western countries, new NPPs were financed using either corporate finance or balance sheet financing model. In this model, instead of a financeable project, a major established utility funds the project from its own resources (mix of retained earnings and debt and equity finance provided on the utility's whole range of assets and not solely on this one new project) (Barkatullah and Ahmad, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). Lenders provide funds to the corporation, and have a claim on its assets in the event of a default. The OECD (2009) made the case that this corporate financing was likely the most common model for new NPPs in many Western nations. A recent example is EDF financing the Flamanville-3 project in France (Barkatullah and Ahmad, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). A major limitation of this model is that the new nuclear project is large enough in scale that it subjects even the largest corporate balance sheet to strain. For instance, an investment of $10 billion on a single project, more than likely this represents a major proportion of an electric utility's market capitalisation and if it suffers credit rating downgrades, would often raise the cost capital rate for the entire company. This makes financing a fleet of new plants by a single corporate entity unlikely, unless it has major support by the state (Barkatullah and Ahmad, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009).

2.5. Contemporary financing models in liberalised and transitional markets

The shift to liberalised electricity markets called for the development of new financing models to work out the substantial revenue and market risks associated with the financing nuclear projects. These models are sophisticated risk transfer mechanisms that provide the revenue certainty demanded by private capital. The literature has gone to great pains to highlight that long-term revenue certainty is essential and not a negotiable condition for attracting private finance to new nuclear projects in liberalised markets (Barkatullah and Ahmad, 2017; OECD Nuclear Energy Agency & International Energy Agency, 2009). As described in the literature, two main instruments have been developed to provide this certainty.

2.5.1. Power Purchase Agreements (PPAs)

A PPA is a long-term contract wherein a buyer, often a state-owned utility or a large industrial consumer, commits to purchasing a specified amount of electricity at a pre-agreed price over a long duration. PPAs insulate the project from wholesale market price risk. The Akkuyu project in Turkey, financed and constructed by Russian Rosatom, is an example. Its bankability is underpinned by a 15-year PPA with the state electricity wholesaler, TETAS, for a significant portion of the plant's output at a fixed price (World Nuclear Association, 2025c; Barkatullah and Ahmad, 2017).

2.5.2. Contracts for Difference (CfD)

The Contract-for-Difference (CfD) is a more sophisticated mechanism to insulate a generator against price risk. Under a CfD, the project is assured a fixed revenue per megawatt-hour, known as the 'strike price'. If the variable market 'reference price' falls below the strike price, the generator receives a top-up payment to make up the difference. If the market price conversely is greater than the strike price, the generator paid back the excess amount. This means that market price risk has been transferred from the project to the CfD counterparty, which is typically a government-backed body, and the costs passed on to electricity consumers (Barkatullah & Ahmad, 2017; World Nuclear Association, 2025c). The Hinkley Point C project in the UK serves as the principal case study for the CfD model. The literature widely acknowledges that the high, 35-year, inflation-indexed strike price was a sine qua non condition for the project to be financed given the extreme amount of construction risk with the developer, EDF (Barkatullah and Ahmad, 2017).

2.5.3. The Regulated Asset Base (RAB) model

The RAB model is a newer innovation in policy, proposed and implemented in the UK to address the financing challenges for future nuclear projects, like Sizewell C. The method is used in the financing monopoly infrastructure networks, such as water systems or electricity grids (World Nuclear Association, 2025c).

$$Allowed\ revenue = Return\ on\ capital\ (WACC\ x\ RAB) + Depreciation + Operating\ costs + Tax + Grid\ costs + Funded\ decommissioning\ programme + Incentives\ or\ penalties\ \&\ other\ adjustments$$

The main feature of the RAB model is to allow the licensed developer to recover its costs and return from consumers through a small addition to electricity bills during the construction period. This allows for a low risk, steady flow of revenue to support the project before it begins generating electricity. Proponents of the RAB model assert that this decreases the cost of capital by eliminating revenue risk as well as allowing the developer to earn returns during the high-risk construction phase. This provides savings for the consumer in the long term as well, potentially £30 billion or greater per project compared to a CfD-financed project (World Nuclear Association, 2025c, Ofgem, 2025).

However, critics of this approach claim that the RAB model creates a transfer of some construction risk (the financial implications of delays and cost overruns) from developers to consumers, which could result in moral hazard or an "open cheque book" for the developer, weakening incentives for strict cost and schedule discipline (Ofgem, 2025). The experience of the Vogtle project in the United States, which utilised a similar mechanism allowing cost recovery from ratepayers during construction and subsequently experienced massive cost overruns passed on to consumers, is frequently cited as a cautionary tale (Ofgem, 2025).

2.6. Alternative ownership and financing structures

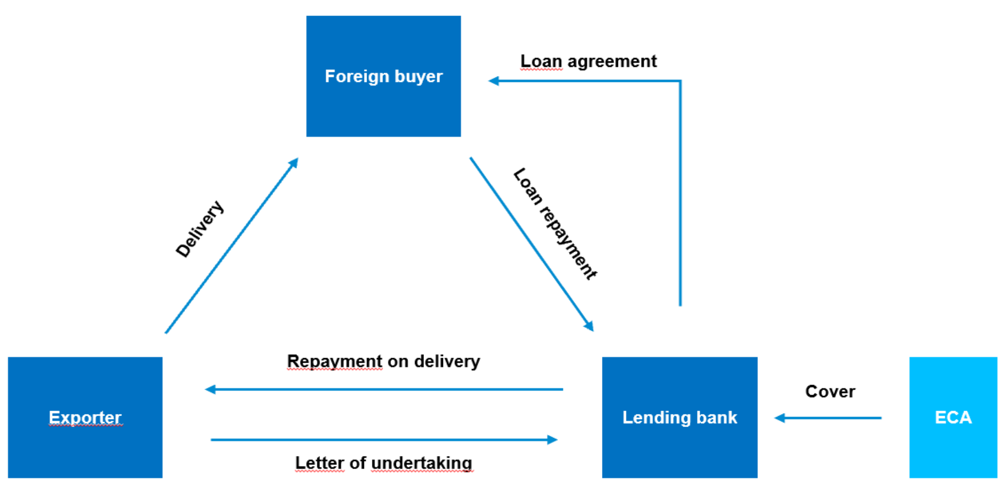
In addition to these principal de-risking mechanisms, some other ownership and financing structures are included within the literature, often together with long term contracts.

2.6.1. Vendor financing and Export Credit Agency (ECA) support

This model is common for projects led by state-owned vendors, with the vendor supplying or arranging a significant portion of the financing, typically as a government to government loan, as a strategy to secure an export contract (Barkatullah and Ahmad, 2017). These projects are typically supported by Export Credit Agencies (ECAs), which provide loan guarantees, political risk insurance, and direct lending at attractive interest rates, often subsidised.

Figure 2.4:

Government financing: ECA financing mechanism



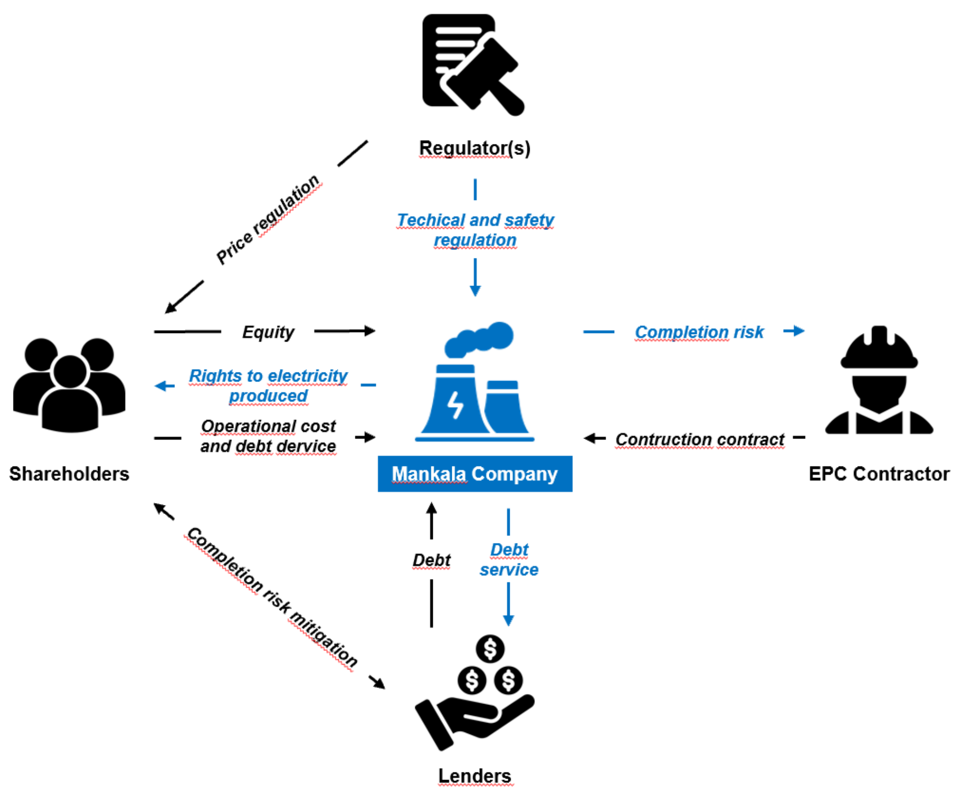
Source: Our elaboration on Barkatullah and Ahmad (2017).

2.6.2. Cooperative and investor-led models: the Mankala model

Another unique structure is the "Mankala" model in Finland. A Mankala company is defined as a consortium of large industrial electricity users and municipal utilities that forms a non-profit company to build and operate a power plant. The shareholders do not receive dividends as with traditional equity investments, instead they are entitled to receive electricity at cost, proportionate to their ownership stake. Through this model, used for instance for the Olkiluoto-3 project by the company TVO, essentially eliminated market risk for the project company, as it has a guaranteed, built-in set of off-takers in its own shareholders (Barkatullah and Ahmad, 2017).

Figure 2.5:

Mankala model and risk diversification



Source: Our elaboration on Barkatullah and Ahmad (2017).

2.6.3. Build-Own-Operate (BOO) and Public-Private Partnerships (PPPs)

The BOO model is a form of PPP where a private entity (typically the vendor) finances, owns, builds, and operates the plant for its entire lifetime. The Akkuyu project in Turkey, developed by Russia's Rosatom, is the first and only application of the BOO model in the nuclear sector to date. The bankability of this model is entirely dependent on the security of the long-term PPA with the Turkish state (Barkatullah and Ahmad, 2017). Table 2.3 offers a comparative summary of these contemporary financing models.

Table 2.3:

Summary of financing models for new nuclear power plants

Financing model	Primary bearer of construction risk	Primary bearer of market (price) risk	Key mechanism	Primary example(s) from literature
Corporate Finance	Developer's Shareholders	Developer's Shareholders	Balance Sheet Financing	Flamanville-3 (France)
Contract for Difference (CfD)	Developer's Shareholders	Consumers/Taxpayers (via CfD Counterparty)	Guaranteed Strike Price	Hinkley Point C (UK)
Regulated Asset Base (RAB)	Shared (Developer & Consumers)	Consumers (via Regulated Return)	Regulated Revenue during Construction	Sizewell C (UK, proposed)
Mankala (Cooperative)	Shareholders (as Consumers)	Shareholders (as Consumers)	Electricity supplied at cost	Olkiluoto-3 (Finland)
Build-Own-Operate (BOO/PPA)	Vendor/Developer	PPA Off-taker (State)	Long-term Power Purchase Agreement	Akkuyu (Turkey)
Vendor/ECA Finance	Shared (Vendor/State & Host State)	Host State (via PPA or Tariff)	State-backed Loan & Guarantees	Paks II (Hungary), Rooppur (Bangladesh)

2.7. SMRs and financial innovation

The literature has begun to examine the role that SMRs may play in addressing the funding problem for large-scale nuclear projects. This outlook focuses on whether their different technical and economic profile may reset the financing paradigm.

2.7.1. The financial case for SMRs

The literature asserts that SMRs could overcome the main funding issues of large-scale NPPs in a number of ways (Weibezahn and Steigerwald, 2024; Mignacca et al., 2020). First, they ensure a lower cost of capital, meaning a smaller total investment per project (likely higher on a kW basis) making it more accessible to a wider range of investors and less likely to create stress on a single corporate balance sheet. Secondly, since SMRs permit one module to be built at a time, they can be built with less total capital and hence less capital at risk. This allows SMRs to begin to make revenue faster, and therefore realize better NPV on their project while providing much earlier timeline for financing (Mignacca et al., 2020). Thirdly, economies of scale: central to the SMR economic proposition is the process of being able to manufacture standardized modules from a factory. The aim is to move cost structure away from the nature of bespoke site construction projects to a manufacturing process, thus reducing cost through learning effects and reduction of many on-site construction risks.

2.7.2. Bankability and financing challenges for SMRs

While these conceptual advantages exist, the literature identifies significant financial burden to deploy SMRs. Primarily, the First-of-a-Kind (FOAK) risk associated with each new design is much more acute. For example, the LCOE of the FOAK SMR is generally expected to be more costly than the LCOE of an Nth-of-a-Kind (NOAK) large reactor, thus making the two initial projects surely uncompetitive (Mignacca et al., 2020).

For SMRs to be bankable, there will need to be an approach in place to overcome this initial cost hump. The literature suggests this is only possible through a credible large order book with multiple customers. An order book with multiple customers will provide manufacturers the demand certainty to make large costs in established factory production lines in order to obtain the cost savings of series production. Hence, the utopia for SMRs is a deeper financing challenge that goes from financing one large project to financing the first high-cost FOAK projects and manufacturing infrastructure. The substantial government support will be necessary: either grants, loan guarantees or the government acting as an anchor customer for the first units to aggregate order book.

2.8. Synthesis and conclusion

There is a wider variety of financing models across national jurisdictions than existed in the past, including now a range of hybrid contractual constructions, but across these financing models the state acts as the ultimate de-risking agent. The literature shows that nuclear financing would include state funding via investment in state-owned utilities or an implicit guarantee of payment via owners and utilities that have cash flows recognized or guaranteed by the government; or state commitment to explicit revenue guarantees such as CfDs or PPAs; or socializing the construction risk through offtake (e.g. RAB); or supporting international nuclear exports through vendor finance/ECA. The involvement of government makes nuclear projects possible for private capital. The review also indicates that purely 'private sector' nuclear plants that are wholly exposed to massive construction risk and market risk in a liberalized market do not model real life. Bankability for nuclear power does not mean the capacity of a project to be profitable, but how the project risks are transferred to consumers and taxpayers who can be compelled by the state to accept them like in the case with construction overruns. Although there is significant literature on financing and bankability, there are several areas that still need further study. Although there is numerous literature about the hope and prospect that SMRs can lower construction costs and therefore be more financeable, there does not appear to be any substantive practical inquiry into the bankability of scaling manufacturing and supply chains for nuclear plants to achieve economies of series production. Additionally, while accounts of some newer models for financing (i.e. RAB and CfD) are well described, there is also limited independent or original long-term data to compare the whole-system costs to consumers associated with these models under conditions of construction overruns. Addressing these gaps in the understanding of nuclear financing and bankability will be key to informing future policy and investment decisions in nuclear power.

3. Structuring the Empirical Dataset for Modelling the Bankability of SMRs

3.1. Key performance parameters

This section establishes the fundamental technical and operational parameters of the small modular reactors (SMRs) being modelled. These variables are critical as they define the performance of the physical asset, which in turn directly determines revenue generation and operating cost profiles. The analysis will focus on two prominent and well-documented SMRs based on pressurised water reactor (PWR) technology: NuScale's VOYGR series and Rolls-Royce's SMR.

3.1.1. NuScale VOYGR series

NuScale's design is based on proven light water reactor (LWR) technology and consists of multiple, independent power modules (NuScale Power Modules™ or NPMs). This modularity is a distinctive feature, enabling scalable plant configurations and incremental deployment. The technology has undergone significant evolution. The original 50 MWe per module design was certified by the U.S. Nuclear Regulatory Commission (NRC) in 2023. Subsequently, a new, upgraded 77 MWe per module design was approved in May 2025, representing the current standard for new implementations. (NuScale Power, n.d.) The thermal capacity of each module is 250 MWt (NuScale Power, 2025) The simulation model must be able to consider different configurations based on the number of modules, which directly affect the total capacity of the plant and the investment profile. Standard configurations include VOYGR-4 (4 modules, for a total of 308 MWe); VOYGR-6 (6 modules, for a total of 462 Mwe); VOYGR-12 (12 modules, for a total of 924 MWe). The operating life of the project is 60 years, a standard assumption for new nuclear plants that defines the time horizon for cash flow analysis (World Nuclear Association, 2025d). For what concerns the capacity factor, NuScale states a target capacity factor of over 95% (NuScale

Power, n.d.). This parameter is a crucial input for calculating annual energy production and, consequently, revenues. The fuel reloading cycle is expected to last up to 21 months, using fuel enriched to less than 5% (NuScale Power, n.d.). This data determines the frequency of scheduled interruptions for maintenance and reloading. Finally, for construction timing, the manufacturer states a construction period of 36 months from the first safety concrete pour (NuScale Power, n.d.). This estimate, provided by the developer, should be considered optimistic and treated as the "low" or "best-case" scenario in a Monte Carlo simulation.

3.1.2. Rolls-Royce's SMR

Unlike NuScale's multi-module approach, Rolls-Royce's design is based on a single, larger, three-loop PWR reactor, which poses important implications for the project risk. This technology is also based on a widely proven Generation III+ PWR design (Rolls-Royce SMR, n.d.). Electrical Capacity (MWe) is 470 Mwe (Rolls-Royce SMR, n.d.). Thermal Capacity (MWth) is 1,358 MWth (Rolls-Royce SMR, n.d.). The design life is 60 years, in line with standards for new nuclear plants, and the capacity factor stated by Rolls-Royce is over 95% (Rolls-Royce SMR, n.d.). The fuel cycle varies between 18 and 24 months, using standard UO_2-based fuel (Rolls-Royce SMR, n.d.). and the refuelling outage has a stated target of only 18 days, an extremely optimistic figure that should be used as a best-case scenario (Rolls-Royce SMR, n.d.) Regarding the construction timeline, although no exact timeline is specified, the goal is to have the first unit operational in the early 2030s (Rolls-Royce SMR, n.d.) The emphasis on factory production, which covers approximately 90% of manufacturing and assembly activities, aims to reduce the time and risks of on-site construction. A range of 3-5 years is a reasonable starting point for modelling.

The divergent design philosophies between NuScale and Rolls-Royce imply inherently different risk and cash flow profiles, which must be captured in the financial model. NuScale's multi-module approach offers the possibility of incremental implementation, where the first module can start generating revenue while the others are still being installed (NuScale Power, n.d.) This translates into early cash flow for a portion of the total capacity. Early cash flow reduces peak financing requirements and the total amount of Interest During

Construction (IDC), directly improving the economics of the project. In contrast, Rolls-Royce's 470 MWe single-unit design follows a more traditional and monolithic project risk profile. Revenues only begin to be generated after the entire plant has been completed and commissioned, following a financing curve typical of large infrastructure projects. Therefore, the very structure of the technology (multi-module vs. single unit) is a key variable for the financing model, not just the total capacity in MWe.

To isolate the impact of financial and construction variables, several key operational parameters will be treated as constants in the simulation, in line with the methodology of Wealer et al. (2021). Specifically, the total plant capacity (MWe) for a given configuration (e.g., 462 MWe), the plant operation period (60 years), and the target capacity factor (95%) will be fixed inputs. This approach ensures that the simulation's output variance is driven by economic uncertainties rather than operational performance assumptions.

Table 3.1

Comparison of key operating parameters

Parameter	Unit	NuScale VOYGR (77 MWe Module)	Rolls-Royce SMR (470 MWe Unit)
Reactor Type	–	Pressurized Water Reactor (PWR)	Pressurized Water Reactor (PWR)
Thermal Capacity	MWt	250 (per module)	1,358
Electric Capacity	MWe	77 (per module)	470
Number of Modules/Units	–	Scalable (typ. 4, 6, 12)	1
Total Plant Capacity	MWe	308, 462, 924	470
Design Lifetime	years	60	60
Target Capacity Factor	%	>95	>95
Fuel Type	–	Standard LWR UO_2	Standard UO_2 (17x17 array)
Fuel Enrichment	%	< 5	< 4.95
Refueling Cycle	months	Up to 21	18–24
Construction Timeframe	years	3 (declared)	3–5 (estimated)

It is essential to recognise that the construction timelines and capacity factors stated by developers represent best-case scenarios. Historical data on large-scale nuclear projects, particularly for “First-of-a-Kind” designs (FOAK), show a tendency toward significant delays and cost overruns, as we have shown in Chapter 2. Moreover, the cancellation of NuScale's UAMPS project due to massive cost escalation, from an estimated $3.6 billion to $9.3 billion, is empirical evidence that should temper these optimistic claims. Consequently, for a robust Monte Carlo simulation, developers' statements should constitute the optimistic limit (e.g., the minimum of a triangular distribution for construction times and the maximum for the capacity factor). The “most likely” and “pessimistic” values should be informed by historical data from nuclear projects and expert opinions.

All monetary figures and results are expressed in constant 2025 USD (real terms); discounting uses a real WACC and no general inflation indexation is modelled.

3.2. Breakdown of SMR cost structure

This section analyses in detail the life cycle costs of an SMR project, which represent the main cash outflows in the financial model. The distinction between “First-of-a-Kind” (FOAK) and “Nth-of-a-Kind” (NOAK) costs is the most critical variable in this section, as it embodies the fundamental economic premise of SMRs.

3.2.1. Overnight Capital Costs (OCCs)

Overnight Capital Cost (OCC) represents the pure capital cost of construction and equipment, excluding financial charges (World Nuclear Association, 2023a). It is a key metric for comparing the intrinsic construction costs of different technologies. In the present analysis, OCC is not treated as a one-time upfront payment but is allocated evenly across the construction years and discounted using the project’s cost of capital. This approach ensures that the timing of expenditures is explicitly captured and that interest during construction is not double-counted.

For FOAK reactors, cost estimates are significantly higher. The International Energy Agency (2025) estimates the costs of FOAK SMRs in the EU at around $10,000/kW, in line with a previous estimate by Boldon & Sabharwall (2014) in the US, providing a range of $7,653/kWe - $10,293/kWe for a single FOAK unit. These values provide a solid range for the probability distribution in the FOAK scenario.

NOAK (Nth-of-a-Kind) refers to subsequent units that benefit from learning effects and mass production. Boldon & Sabharwall (2014) predict that NOAK costs will fall to a range between $5,079/kWe and $6,831/kWe. The IEA predicts that, in optimistic scenarios, cost parity with large reactors (around $6,600/kW) could be achieved by mid-century (International Energy Agency, 2025). An MIT study by Shirvan (2024) estimates a NOAK cost for the AP1000 reactor of $4,625/kW, providing a useful benchmark for mature Gen III+ technology.

Overnight Capital Cost (OCC) is a primary stochastic variable in this analysis. For FOAK projects, we will model OCC using a Lognormal distribution to better capture the significant potential for extreme cost overruns, as evidenced by the NuScale UAMPS case. The distribution will be defined by a base case of $10,000/kW, with a low of $7,700/kW and a high of $12,500/kW. For the mature Nth-of-a-Kind (NOAK) scenario, which assumes learning effects have been realized, OCC will be modelled with a Triangular distribution, defined by a low of $4,600/kW, a base (most likely) of $6,000/kW, and a high of $6,800/kW.

3.2.2. Learning curve and modularization

With regard to the impact of modularization, the SMR business model relies on the principle of 'mass production economies' to overcome the 'diseconomies of scale' associated with smaller reactors. The Boldon & Sabharwall (2014) study assumes a technology learning rate of 4.5% for the transition from FOAK to NOAK, which leads to a reduction of nearly 50%

in the total capital investment cost[8]. This learning rate should be a key stochastic variable in the simulation model.

3.2.3. Interest During Construction (IDC)

IDCs represent the financial costs accumulated during the construction period, before the plant generates revenue, and constitute a significant component of the total project cost (World Nuclear Association, 2023a). The shorter construction times reported for SMRs (e.g. 3-5 years) compared to large reactors (e.g. 6-15 years) are a key factor in reducing total costs, even with a higher OCC. A GLOBSEC analysis shows that an SMR with an OCC of $10,000/kW and a construction time of 5 years can have a lower total cost than a large reactor with an OCC of $6,600/kW and a construction time of 15 years, solely due to lower accumulated IDCs (GLOBSEC, 2025). This highlights that the construction period is a critical driver of Interest During Construction (IDC) and overall project viability. This will be modelled as a stochastic input using a Triangular distribution. Based on developer claims and historical precedent for delays, the FOAK construction period will be modelled with a range of 3 years (optimistic), 5 years (most likely), and 8 years (pessimistic). For the NOAK scenario, reflecting a mature supply chain, the range will be narrowed to 3 years (optimistic), 4 years (most likely), and 5 years (pessimistic). IDC is not added as a separate markup: it is endogenously reflected by discounting the year-by-year OCC outlays over the stochastic construction period at the simulated WACC.

3.2.4. Operation & Maintenance costs (O&M)

O&M costs can be divided into fixed and variable components, although for nuclear plants they are predominantly fixed. Boldon & Sabharwall (2014) consider a value of $18/MWh to be a reasonable estimate for water-cooled SMRs. The same study also cites a range from $12.05/MWh (NOAK) to $25.49/MWh (FOAK), providing an excellent basis for defining a

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[8] The learning rate, often associated with Wright's Law, posits that for every cumulative doubling of units produced, the cost per unit decreases by a consistent percentage. A 4.5% learning rate implies that the cost of the 2nd unit would be 95.5% of the 1st, the 4th unit would be 95.5% of the 2nd, and so on.

probability distribution. As a comparison, existing large reactors in the United States recorded total generation costs (including capital and fuel) of approximately $31.76/MWh in 2023, with O&M costs representing a significant component (Nuclear Energy Institute, 2025a). Total O&M costs will be modelled as a single variable in $/MWh. Referencing Boldon & Sabharwall (2014), this variable will follow a Uniform distribution ranging from $12.05/MWh (representing a mature, efficient NOAK plant) to $25.49/MWh (representing a higher-cost FOAK plant).

3.2.5. Fuel cycle costs

The World Nuclear Association (2023a) includes among the costs of the fuel cycle the uranium (U3O8) mining, conversion, enrichment and fuel fabrication. The resulting total costs are approximately $1,663–1,787 per kg of finished fuel. Fuel cycle costs, while variable in reality, represent a relatively small and stable portion of the total LCOE for nuclear plants. To maintain focus on the primary drivers of financial risk, the fuel cost will be treated as a constant at $5.32/MWh, based on the 2023 average for the U.S. fleet as reported by Nuclear Energy Institute (2025a).

3.2.6. Decommissioning and waste management costs

Decommissioning costs are substantial, but since they are spread over a very long time horizon, their present value contributes only a small fraction to the LCOE. Estimates indicate that these costs range between 9% and 15% of the initial capital cost (World Nuclear Association, 2023a). In the United States, they represent approximately $0.10-0.20/MWh. The Hinkley Point C project includes a detailed Funded Decommissioning Programme (FDP), which sets a precedent for how these costs are managed contractually (Department for Energy Security and Net Zero – UK Government, 2016).

The entire business case for SMRs critically depends on the transition from FOAK to NOAK. The data clearly show that FOAK SMRs, with OCCs around $10,000/kW, are not economically competitive with other sources of generation, such as combined cycle gas

(LCOE $48-109/ MWh) or even new large nuclear reactors (LCOE $141-220/MWh) on a pure cost basis (Lazard, 2025). The bankability of SMRs is therefore entirely contingent on achieving the steep cost reductions promised by NOAK production. Consequently, a Monte Carlo simulation cannot treat the learning rate as a fixed assumption. The learning rate itself, the number of units needed to achieve it, and the time horizon should be modelled as key stochastic variables.

Furthermore, cost escalation is not a theoretical risk, but a quantifiable reality. The increase in the cost of NuScale's UAMPS project from $3.6 billion for 720 MWe in 2020 to $9.3 billion for 462 MWe in 2023 represents more than a tripling of the cost per kW, from approximately $5,000/kW to over $20,000/kW. 3 This real-world case demonstrates that initial cost estimates can be extremely inaccurate due to supply chain issues, inflation, and increased complexity revealed during the detailed engineering phases. This implies that probability distributions for Capex in the Monte Carlo model should have a significant “long tail” or be skewed towards higher costs, especially for early projects. A symmetrical distribution (such as a normal distribution) may not adequately capture this risk; a lognormal or skewed triangular distribution would be more appropriate.

In the simulation, decommissioning is operationalised as a per-MWh levy that reduces operating margin each year. The levy is drawn from a Uniform distribution of $1–$3/MWh (real) to span typical policy settings and programme uncertainty.

3.3. Financing structures and cost of capital

We define two distinct financial universes for the SMR project: a low-risk model, supported by the government, and a high-risk model, fully exposed to the market (merchant). There is a difference in the Weighted Average Cost of Capital (WACC) between these two worlds. For the Monte Carlo, the WACC is sampled directly to reflect financing uncertainty: Regulated 2.5–4.5% (real, Uniform) and Merchant 7.5–10.0% (real, Uniform). Debt assumptions used for bankability metrics are 60% debt / 40% equity, 25-year amortising tenor, annuity repayment, and a real cost of debt drawn 1.5–3.0% in regulated scenarios and 3.5–6.0% in merchant scenarios. DSCR and LLCR are then computed from CFADS and debt service using the standard definitions introduced in Chapter 2.

3.3.1. The regulated financing model (low-risk scenario)

This model assumes that the SMR project benefits from a stable, long-term revenue mechanism, such as a Contract for Difference (CfD) or a Regulated Asset Base (RAB) model, which significantly reduces the risk for investors. The closest real-world analogy is a regulated utility asset. Therefore, we use NERA Economic Consulting (2018) to derive the parameters to be used in the Capital Asset Pricing Model (CAPM). Cost of equity is the range of 5.7% to 6.7%. Cost of Debt is 1.0%. For regulated assets, in fact, the cost of debt is generally very low, reflecting the low risk of default. Beta is estimated in the range of 1.2 - 1.3. To complete the WACC calculation, we reasonably assume a gearing (i.e., debt / equity ratio) of 45%. The combination of these parameters results in a vanilla WACC of 3.5% - 4.1%. These parameters frame plausible ranges; however, in the simulation WACC is not computed bottom-up. Instead we draw it directly from 2.5–4.5% (real) for regulated cases to reflect the full uncertainty band observed in practice.

3.3.2. The financing model for merchant projects (high risk scenario)

This model assumes that the SMR project is fully exposed to the volatility of wholesale electricity prices, without any public support for revenues. This is a high-risk proposition due to the high capital costs and long construction times of nuclear assets. The main difference lies in the much higher cost of equity required by investors to compensate for revenue uncertainty. Lazard's generic assumption for U.S. Nuclear is 40% equity at a cost of 12% and 60% debt at a cost of 8%, implying a nominal after-tax WACC of 7.7% (Lazard, 2025). This should be considered the minimum or most optimistic case for a merchant nuclear project. Academic and industry analysis suggest that the cost of capital for merchant generation is significantly higher. Regarding gearing, merchant projects cannot sustain the same level of debt. Lower gearing, e.g. 50% debt/50% equity, is more realistic and further increases

WACC, as the proportion of equity, which is more expensive, grows. The gap between a regulated WACC (around 4%) and a merchant WACC (more than 8%) is immense. Over a 60-year project life cycle, this difference in discount rate will be the single largest determinant of the project's Net Present Value (NPV) and, therefore, its bankability. The LCOE formula is extremely sensitive to WACC as we have seen in Chapter 2.

However, the financing structure is not binary, but a spectrum. The real world includes hybrid models. For example, the Vogtle project in the United States received a federal loan guarantee of $6.5 billion, which reduces the cost of debt without completely eliminating project risk for shareholders. The British government offered a £2 billion debt guarantee for Hinkley Point C. These mechanisms fall between fully regulated and fully merchant models. A "hybrid" scenario should therefore be modelled with a capital structure that has a low cost of debt (similar to the regulated case) but a high cost of equity (similar to the merchant case). This will produce a WACC intermediate between the two extremes, providing a more nuanced analysis.

Therefore, rather than calculating WACC from its components, we will model the WACC itself as a primary stochastic input to reflect the broad uncertainty in financing costs. For the regulated/low-risk scenarios, WACC will be modelled using a Uniform distribution ranging from 2.5% to 4.5%. For the merchant/high-risk scenarios, the WACC will also follow a Uniform distribution, but with a significantly higher range of 7.5% to 10.0%. This aligns with the ranges identified by Lazard and academic literature and directly models the single largest determinant of the project's NPV.[9]

[9] In the simulation, a Gaussian-copula approach is applied to introduce moderate positive correlation between overnight capital costs (OCC), construction duration, and the weighted average cost of capital (WACC). The correlation matrix used is: [[1.00, 0.50, 0.30], [0.50, 1.00, 0.30], [0.30, 0.30, 1.00]]. This reflects the tendency for higher OCC and longer build times to coincide with tighter financing conditions.

3.4. Revenue modelling

This section defines the project's cash inflows. It mirrors the previous section by creating two distinct revenue scenarios: a stable flow based on contracts and a volatile flow based on the market.

3.4.1. CfD-based revenue model

A CfD is a long-term contract that guarantees a fixed ‘strike price’ for each MWh generated. The generator sells the energy on the wholesale market. If the market ‘reference price’ is lower than the strike price, it receives a compensatory payment. If it is higher, it returns the difference (Watson & Bolton, 2024). This mechanism effectively eliminates the wholesale price risk for the generator. The CfD for Hinkley Point C serves as an excellent case study, with a strike price of £92.50/MWh in 2012 prices, which reduces to £89.50/MWh if the Sizewell C project goes ahead, indexed to inflation, and a contract duration of 35 years (Department for Energy Security and Net Zero – UK Government, 2016).

To provide realistic input for the model, we adjusted for inflation using data from the UK Retail Price Index (RPI). The index value for 2012 was 242.7. For the second quarter of 2025, the index was 403.2. The cumulative inflation factor is 403.2 / 242.7 = 1.661. Therefore, the adjusted price in 2025 GBP is £92.50 × 1.661 = £153.64/MWh. Finally, to convert this figure to US dollars, we apply a representative exchange rate. Using a rate of 1.25 USD/GBP, the final converted strike price is $192.05/MWh (£153.64 × 1.25). This value will be used as the constant revenue stream in the model’s regulated, low-risk scenarios[10].

3.4.2. Merchant revenue model

While electricity prices follow a complex stochastic process, for this project finance analysis we will model the long-term average wholesale price as a single stochastic variable. This

[10] Modelling note: in the base case we apply this constant real price across the full operating life as a proxy for a regulated-tariff regime; robustness checks with a 35-year CfD followed by merchant prices are reported in the sensitivity analysis.

simplifies the model while still capturing price uncertainty's impact on project NPV. Aligned with the methodology of Wealer et al. (2021) and market analysis from McKinsey, the wholesale electricity price for the merchant scenario will be drawn from a Uniform distribution ranging from \$60/MWh to \$90/MWh (in 2025 currency).

3.5. Summary of the model and sensitivity testing

All cash flows and inputs are in constant 2025 USD (real terms). Each scenario is simulated with 100,000 Monte Carlo draws. Debt is set at 60% of OCC with a 25-year annuity repayment used for coverage metrics. Bankability ratios are computed from CFADS over the debt tenor (DSCR) and the present value of CFADS at COD discounted at the cost of debt (LLCR). Table 3.2 summarises the inputs used for the model.

Table 3.2:

Summary of Inputs for Monte Carlo Simulation

Parameter	Distribution	Range	Units
Stochastic Variables			
Overnight Construction Cost (FOAK)	Lognormal	Base: 10,000	USD/kW
Overnight Construction Cost (NOAK)	Triangular	4,600–6,800	USD/kW
Construction Period (FOAK)	Triangular	3–8	Years
Construction Period (NOAK)	Triangular	3–5	Years
Weighted Average Cost of Capital (Regulated)	Uniform	2.5–4.5	%
Weighted Average Cost of Capital (Merchant)	Uniform	7.5–10.0	%
Cost of Debt (Regulated)	Uniform	1.5–3.0	%
Cost of Debt (Merchant)	Uniform	3.5–6.0	%
Decommissioning levy	Uniform	1–3	USD/MWh
O&M Costs	Uniform	12.05–25.49	USD/MWh
Wholesale Price of Electricity (Merchant)	Uniform	60–90	USD/MWh

Constants			
Plant Capacity to Grid	Constant	462	MWe
Plant Operation Period	Constant	60	Years
Capacity Factor	Constant	0.95	–
Fuel Cost	Constant	5.32	USD/MWh
CfD Strike Price (Regulated)	Constant	192.05	USD/MWh
Debt / Total Capex	Constant	60	%
Loan Tenor	Constant	25	Years
Number of Experiments (n)	–	100,000	–

The analysis shows that the bankability of an SMR project is predominantly determined by two main factors. Firstly, the revenue mechanism and the resulting cost of capital. A project with revenues guaranteed by a long-term contract such as a CfD will face a significantly lower WACC (in the range of 2.5-4.5% real) than a project exposed to merchant market volatility, where the WACC can easily exceed 6.5-9.5% real. This difference in discount rate has an exponential impact on the Net Present Value (NPV) of the project.

Secondly, the ability to move from high FOAK costs to low NOAK costs is the cornerstone of the SMR business model. FOAK costs, estimated at around $10,000/kW, are not competitive in most markets. Only by achieving NOAK costs, potentially below $6,000/kW thanks to learning rates and economies of mass production, can SMRs become economically viable, especially in a merchant context. Combining the two main variables (financing structure and cost maturity stage) generates four main scenarios to analyse, summarized in the table below:

Table 3.3:

Summary of the 4 scenarios analysed

Scenario	Description	Favourability	Key features
Regulated / NOAK	Mature SMR market under regulated framework with strong political support.	Most favourable	Stable revenues via cost-of-service regulation; proven technology; reduced financing risk.
Regulated / FOAK	First-of-a-kind SMR projects backed by government support to overcome initial high costs.	Supportive, but risky	Political backing, subsidies, or guaranteed cost recovery; higher construction and technology risk.
Merchant / NOAK	Advanced, cost-competitive SMRs in merchant power markets.	"Holy grail" scenario	Market-driven revenues; technology proven and competitive without subsidies; attractive for investors.
Merchant / FOAK	Early SMR projects in merchant markets without subsidies.	Least favourable	High costs, high risk, unbankable; serves as benchmark for level of support needed.

The model built with this dataset can answer critical research questions for policymakers and investors, we will focus on:

1. *How do Overnight Capital Costs (OCCs) and construction times influence the bankability of SMR projects under merchant market conditions?*
2. *How does the introduction of a CfD-backed regulated framework affect project NPVs compared to merchant models, and what does this imply for public policy support?*
3. *Under what wholesale electricity price conditions can merchant NOAK SMRs achieve competitive NPVs and acceptable debt coverage ratios?*
4. *What is the probability that SMR projects across the four scenarios (Regulated/FOAK, Regulated/NOAK, Merchant/FOAK, Merchant/NOAK) achieve a positive NPV, given the uncertainty around costs, construction periods, and financing?*

The following chapter addresses these questions, presenting a detailed empirical analysis of the conditions required for Small Modular Reactors to achieve financial bankability.

4. Empirical Results

This chapter will discuss the Monte Carlo simulation results across the four scenarios: Regulated/FOAK, Regulated/NOAK, Merchant/FOAK and Merchant/NOAK. The results are presented in terms of project net present value (NPV), debt service coverage ratio (DSCR) and loan life coverage ratio (LLCR). Discussion will include both scenario-specific findings and the comparative evaluation across scenarios.

4.1. Scenario-by-scenario results

4.1.1. Regulated FOAK

The Regulated/FOAK scenario yields consistently positive outcomes, with a mean NPV of approximately \$9.3 billion and a 100% probability that NPV>0. Although the NPV distribution is fairly wide, the downside risk is limited (5th percentile is approximately \$5.7 billion). The DSCR profile is particularly strong: the fifth percentile minimum DSCR is above 3.3, which is well above the 1.3x covenant threshold, therefore the probability of covenant failure is basically zero. LLCR results support this, with a median of 4.4.

Table 4.1:

Summary statistics across the four scenarios

Metric	Regulated FOAK	Regulated NOAK	Merchant FOAK	Merchant NOAK
Mean NPV (\$bn)	9.305	11.609	-2.173	-0.641
NPV p5 (\$bn)	5.717	8.594	-3.195	-1.247
Median NPV (\$bn)	9.140	11.419	-2.170	-0.663
P(NPV>0) %	100.0	100.0	0.013	6.224
Min DSCR p5	3.392	6.488	0.625	1.122
P(Min DSCR<1.30) %	0.0	0.0	86.321	15.506
Median LLCR	4.414	7.518	0.984	1.688

Figure 4.2:

NPV distribution histogram – Regulated FOAK

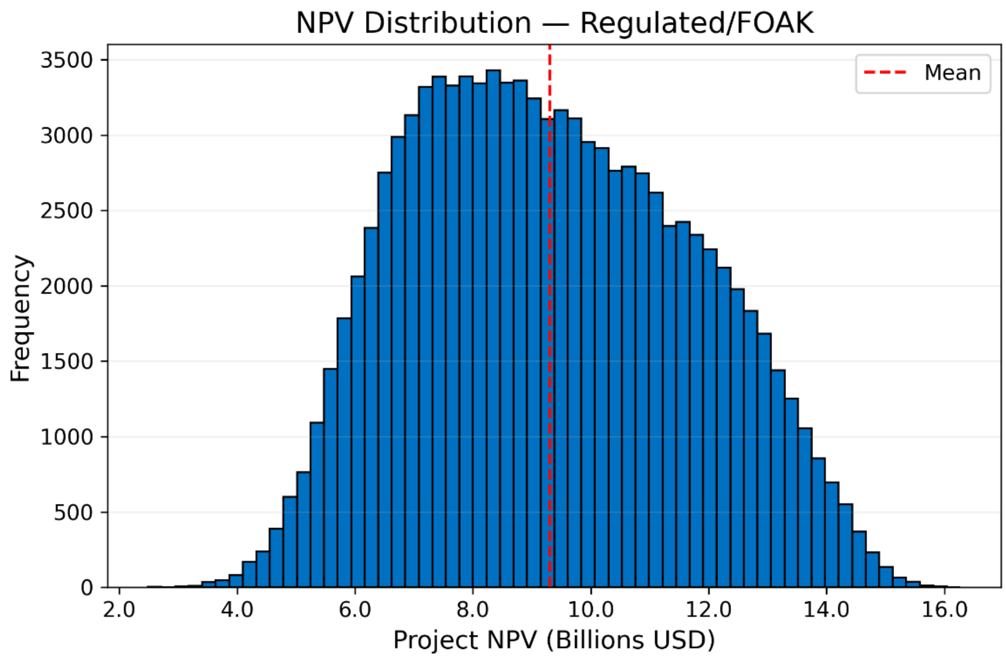
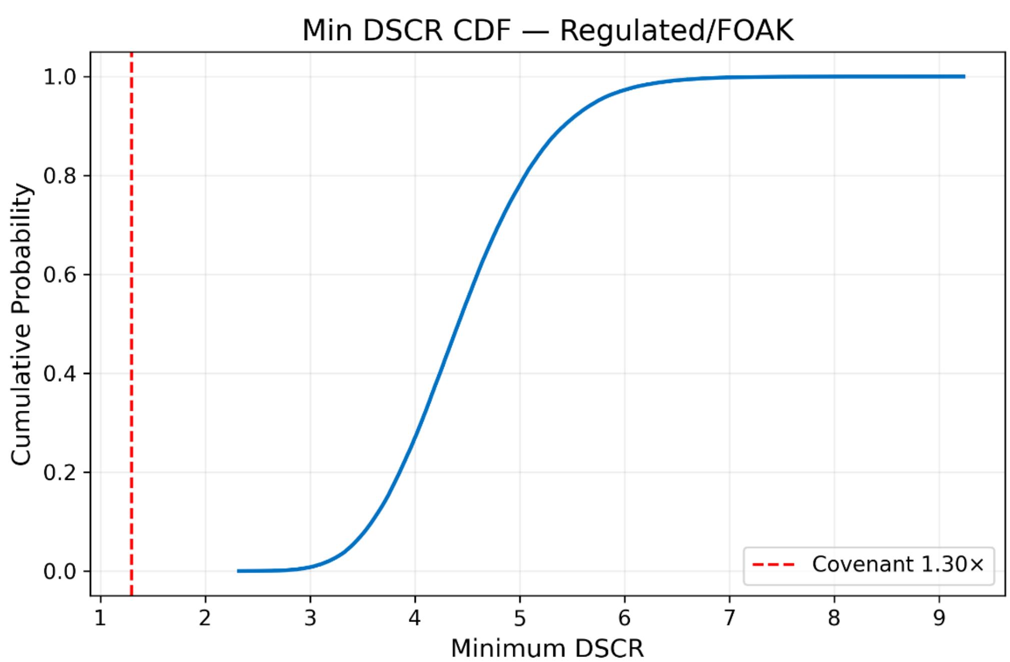


Figure 4.3:

DSCR CDF – Regulated FOAK



4.1.2. Regulated NOAK

The Regulated/NOAK case is an even stronger performer, with mean NPV of approximately $11.6 billion and a 100% probability that NPV>0. The learning effects incorporated in the NOAK assumptions have shifted the NPV distribution up, with a five percentile of $8.6 billion. Minimum DSCRs are similarly strong, with the fifth percentile DSCR above 6.5. The probability of covenant failure is again nil. The LLCR median rises to 7.5. This illustrates that along with technological maturity, regulatory frameworks yield an extremely bankable outcome.

Figure 4.4:

NPV distribution histogram – Regulated NOAK

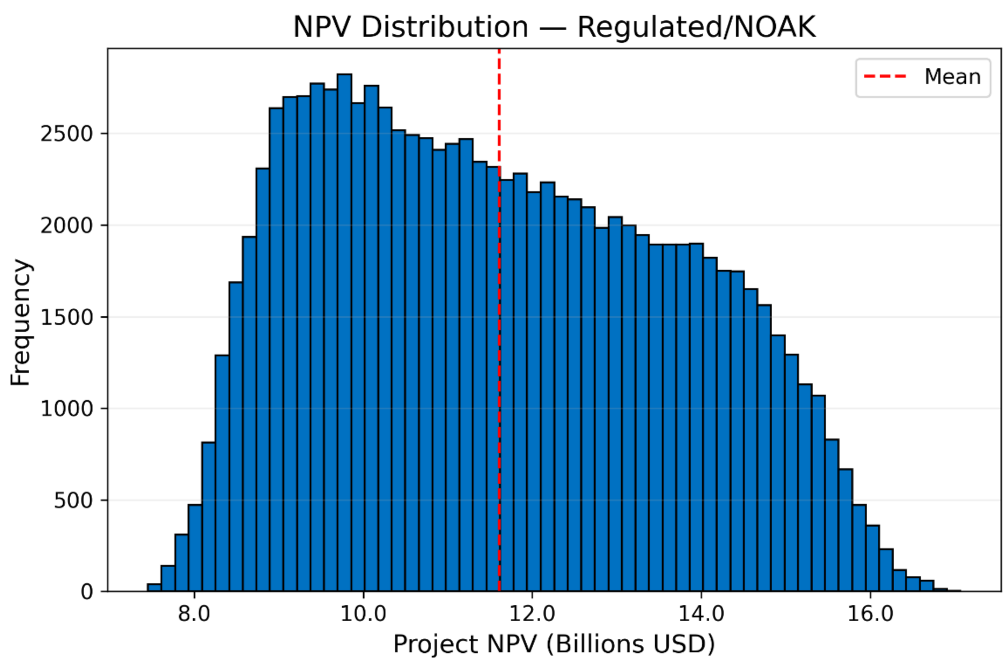
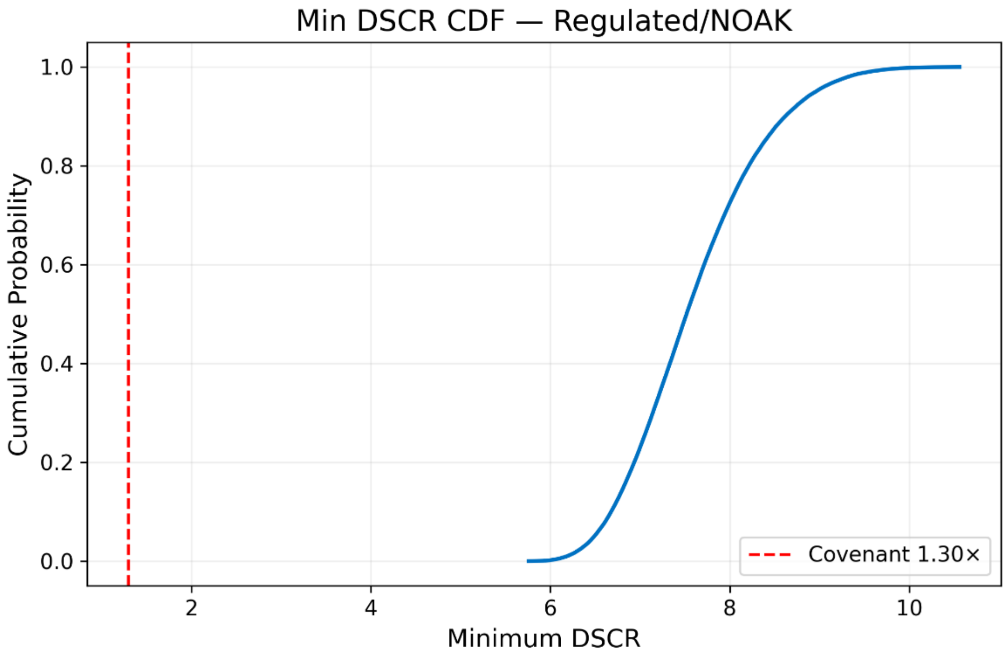


Figure 4.5:

DSCR CDF – Regulated NOAK



4.1.3. Merchant FOAK

In contrast, the Merchant/FOAK scenario is economically unviable for the majority of the project simulations. The mean NPV is negative, approximately –$2.2 billion, with a fraction of only 0.01% of the simulations yielding a positive NPV. The 5th percentile lays out at –3.2 billion, which reinforces the structural unfeasibility of FOAK merchant plants to recover costs in the absence of regulated revenue from utilities. The DSCR distribution shows the most severe bankability issues: the 5th percentile minimum DSCR is only 0.6 and over 86% of the simulations fell below the 1.3x threshold. The median LLCR drops at below 1.0, which shows insufficient cover for the duration of the loan period.

Figure 4.6:

NPV distribution histogram – Merchant FOAK

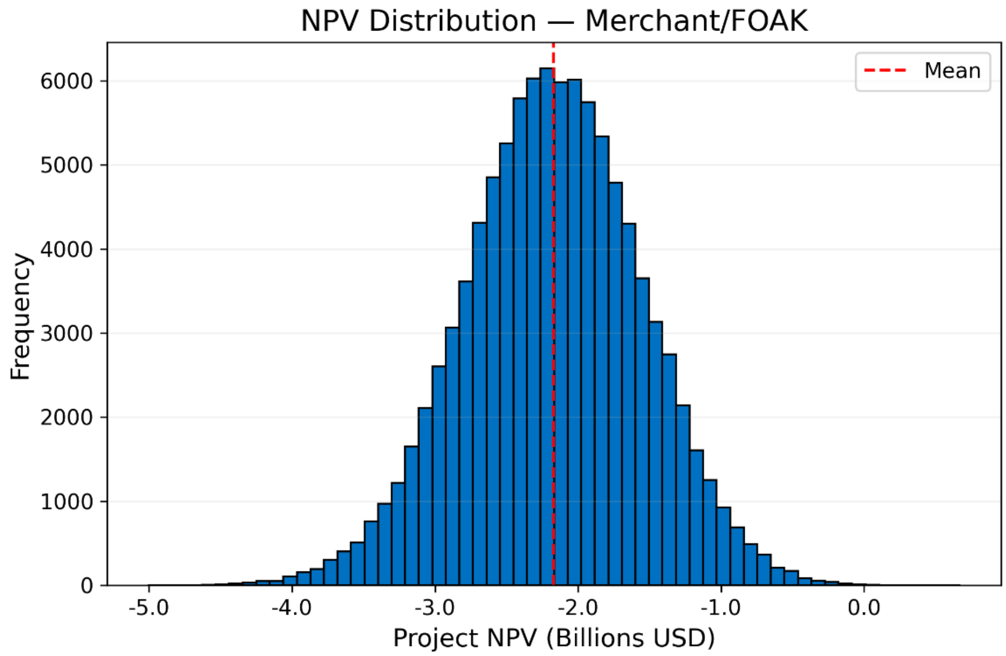
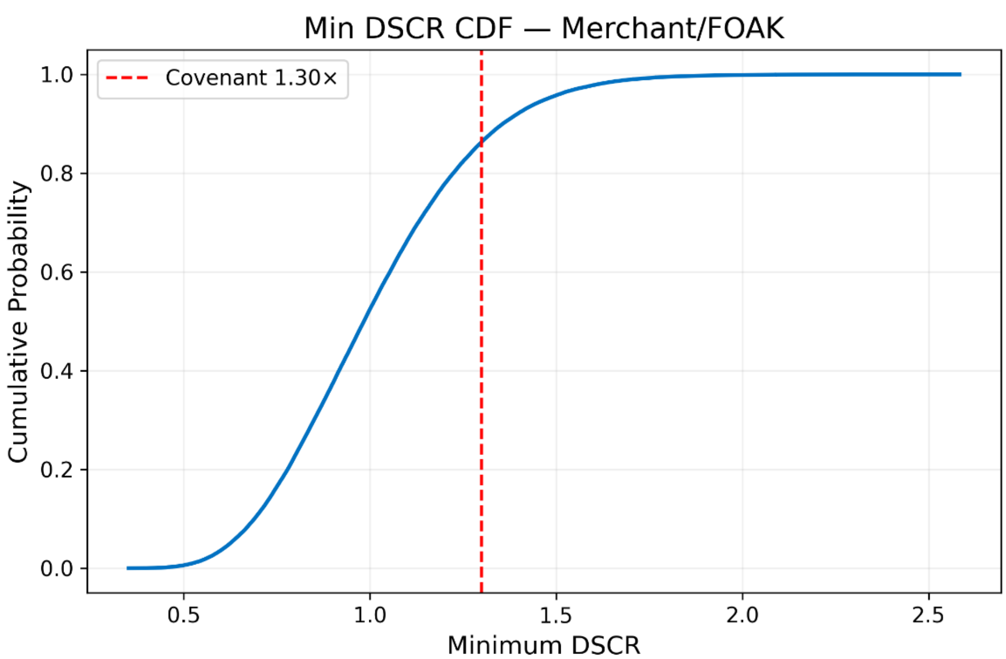


Figure 4.7:

DSCR CDF – Merchant FOAK



4.1.4. Merchant NOAK

The Merchant/NOAK scenarios did show modest improvements with learning effects, but results remained weak. The mean NPV was still negative (–\$0.6 billion) and the associated probability of positive NPV improves modestly to 6.2%. From a bankability perspective, the picture improved; the probability of a DSCR < 1.3x fell to about 15.5%, compared to the FOAK case where the probability was 86%. However, significant potential for covenant breach still remained and median LLCR levels were again well below those for regulated scenarios.

Figure 4.8:

NPV distribution histogram – Merchant NOAK

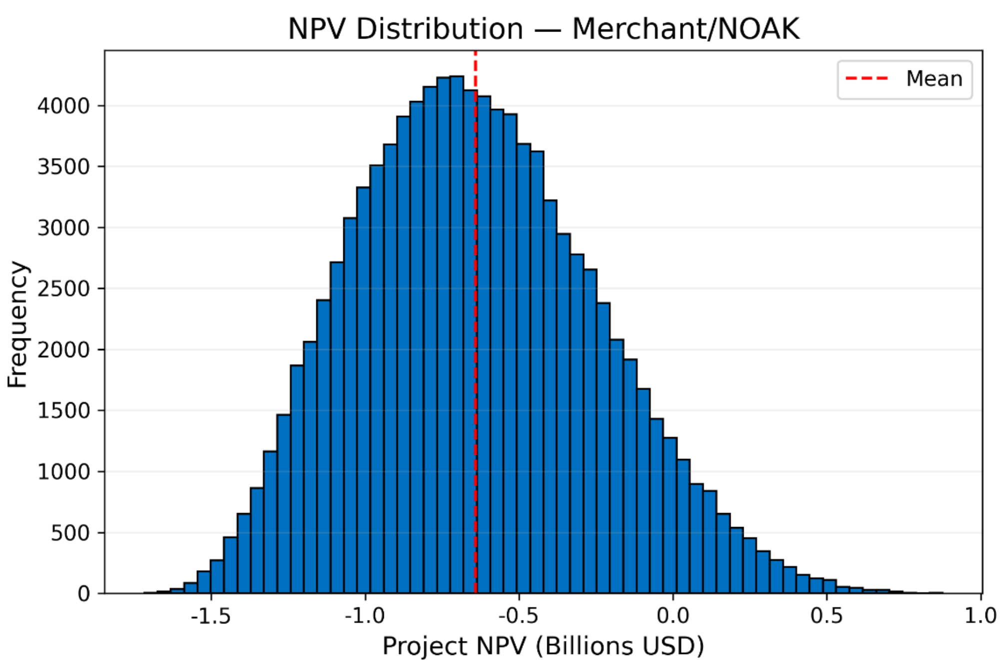
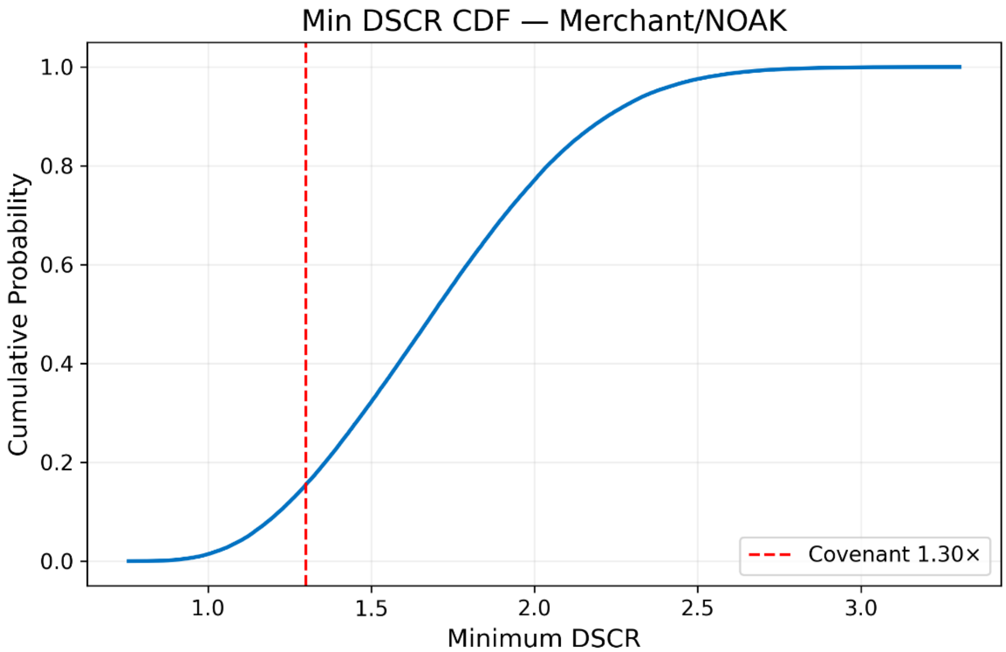


Figure 4.9:

DSCR CDF – Merchant NOAK



4.2. Comparative analysis across scenarios

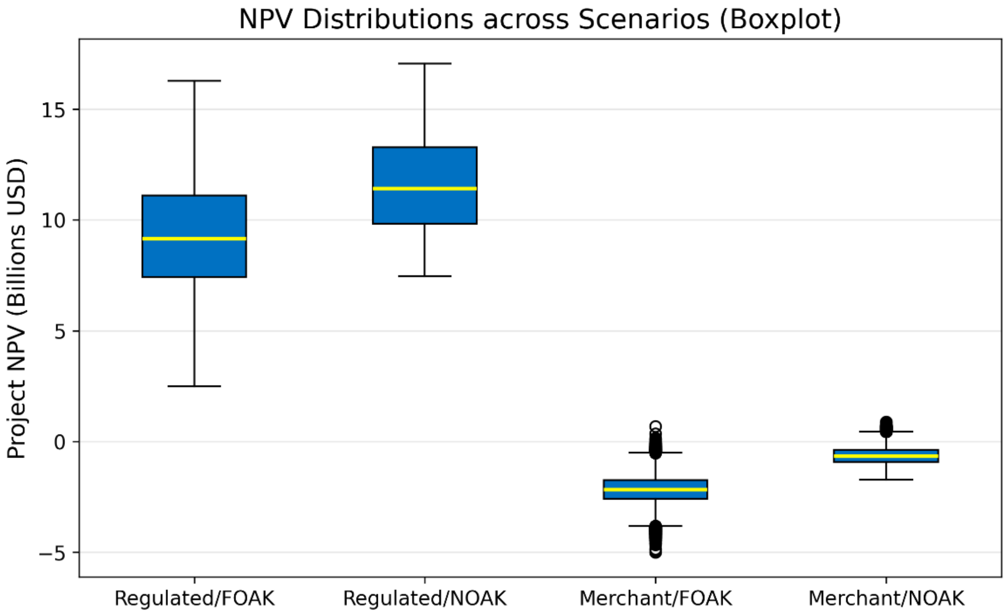
While individual scenario analyses are a useful way of examining the particulars of a project, a comparative context offers an important appreciation of the structural differences between regulated versus merchant regulatory structures and exposure, as well as distinguishing FOAK from NOAK technologies.

4.2.1. Comparative NPV distributions

Figure 4.10 comprises boxplots of NPV distributions across the scenarios. The contrast between regulated and merchant structures is evident. The regulated cases are clustered around strongly positive NPVs while merchant cases are located in negative NPV territory and clustered as well. The NOAK learning effect is apparent in both regulated and merchant distributions where gains from NOAK learning pushed both distributions higher, but it was insufficient to overcome unfavourable merchant economics.

Figure 4.10:

Comparative boxplot of NPVs across scenarios

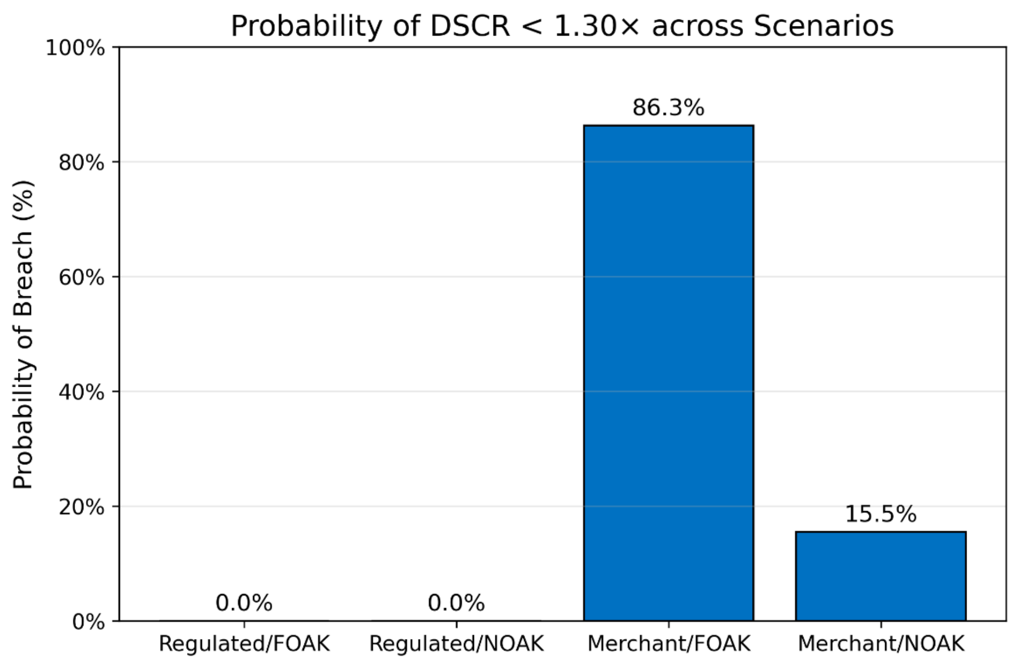


4.2.2. Probability of DSCR breach

The probability that DSCR is below the 1.3x covenant threshold indicates something more straightforward about the debt sustainability. The probability of breach for regulated projects is essentially zero whether FOAK or NOAK status is considered (Figure 4.11). Conversely, FOAK plants that are merchant experience an unacceptably high breach probability of 86%. Merchant NOAK, on the other hand, is 15.5% breach and a NOAK probability of breach in excess of 10% is a poor outcome with respect to financing standards.

Figure 4.11:

Probability of DSCR < 1.3x across scenarios



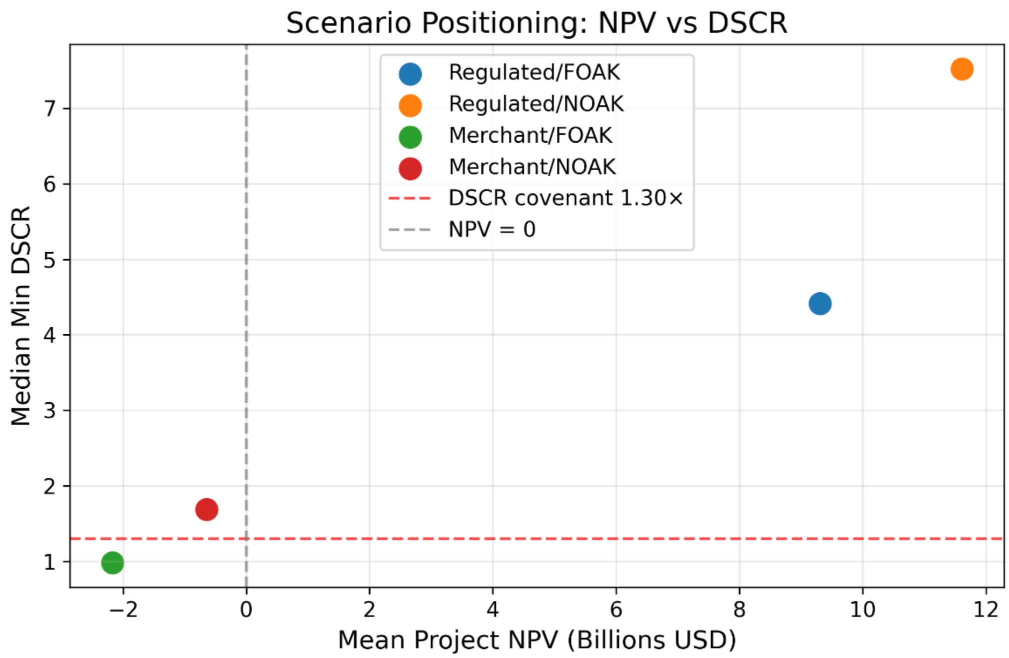
4.2.3. Scenario positioning: NPV vs DSCR

A final synthesis of NPVs and DSCR is achieved simply by plotting the mean NPVs against the median minimum DSCRs for each scenario (Figure 4.12). This quadrant visibility provides two distinct clusters: (i) Regulated scenarios at the top-right quadrant with both positive NPVs and strong DSCRs signalling strongly bankable projects; (ii) Merchant scenarios at the bottom quadrants with negative NPVs (FOAK) or weak DSCRs (NOAK).

This scatter plot demonstrates why merchant nuclear investments struggle to attract private financing without regulatory or contractual support.

Figure 4.12:

Quadrant scatter of mean NPV vs median DSCR across scenarios



4.3. Discussion of findings

Most significantly, the results underline a traditional observation: the bankability of SMR projects is fundamentally determined by the regulatory framework. While project economics are marginally improved by lowering costs at the NOAK phase, merchant exposure fails to be consistent with any systematic project finance requirements as evidenced by negative NPVs and substantial DSCR breach probabilities. Regulated projects, including FOAK cases, consistently generate NPVs at a significantly higher level with coverage ratios that indicate they are consistent with investment grade expectations. These findings also reinforce an indication that as important as technological maturity, perhaps even more, in determining the viability of SMRs are policy and regulatory design features.

Conclusions

This thesis was designed to research the critical financial conditions for Small Modular Reactors (SMRs) to be bankable investments, so that they can make a meaningful contribution to global decarbonisation and energy security goals. The central research problem was framed not as a question of technology feasibility but rather financial viability. Given the degree of uncertainty typically involved in nuclear energy project develop, ranging from uncertainty on the construction costs, through to uncertainty on the longer term market dynamics, this research did not take a deterministic approach and instead developed and applied a stochastic financial model, using a Monte Carlo simulations approach, to measure the differences in financing structures, and phases of technological maturity, on the economics and credit profile of a typical SMR project.

The analysis was shaped around four scenarios to firstly reflect the important interaction between engineering and policy, and secondly to test a FOAK (first of a kind) and mature NOAK (Nth of a kind) SMR project operating under two quite different revenue structures; a regulated Contract for Difference (CfD) that provides certainty over the long term revenues of the project, and a fully deregulated merchant market which incorporates the full variability of wholesale electricity prices. Following 100,000 simulations of each scenario, this research provided a clear empirical foundation to make conclusions on SMR bankability. The financial metrics characterising the project performance; particularly the NPV to equity investors, and the Debt Service Coverage Ratio (DSCR) for lenders, were fully characterised and led to several clear, unambiguous and mutually confirming conclusions.

The empirical results in Chapter 4 provide a strong and obvious story narrative. The analysis showed that there were several contributors to the financial outcome of a SMR project, however bankability of a SMR project is overwhelmingly determined by one dominant factor: the regulatory and contractual arrangements of the SMR project.

The most significant conclusion from this research is the strong and clear directional influence of the revenue mechanism, on every measure of financial success. The simulation shows a distinct divide between the projects operating under a regulated structure and merchant market risk.

The scenarios with regulated revenue structures, supported by long-term inflation-indexed contract for differences, were 100% bankable. The analysis showed consistently strong positive NPVs, with strong DSCRs that remained comfortably above the typical lenders covenants throughout most of the sampled outcomes. The CfD, by transferring the wholesale price risk of the project to a government supported counterparty, provided certainty and insulation from the risk of variance of cash flows for the project. By keeping the project cash flow insulated from inevitable price fluctuations in the market, this provides a very significant shift in the project financial profile, with much lower WACC, the impact of which on NPV is exponentially positive for large long-lived capital assets. The findings supported the theoretical position in Chapter 2, that for capital intensive technologies such as nuclear, risk allocation will be a more powerful financial lever than virtually any other variable used in the project evaluation.

On the other hand, merchant scenarios were determined to be largely unbankable, with negative mean NPVs and high probabilities of DSCR covenant breach. The results provide strong evidence of a structural mismatch between a nuclear asset's economic profile (high fixed costs, low marginal costs) and the functioning of the electricity market in its liberalised form. Even with optimistic assumptions regarding future electricity prices, the market risk remains too great for the project to service its debt reliably, let alone generate a sufficient return for equity investors.

A major assumption for the SMR business case is the prospect of cost reduction through serial manufacturing, moving from a generally expensive FOAK unit to a cost-competitive NOAK fleet. The simulation indicates this learning effect is real and economically meaningful. In the merchant scenario, for example, the average NPV was improved by transitioning from FOAK to the NOAK phase of the project, from an average loss of -$2.2 billion to -$0.6 billion, and the probability of DSCR covenant breach would be reduced from 86.3% to 15.5%.

However, the second critical conclusion of this thesis is that while technological maturation is important, it is insufficient alone to close the viability gap. A 15.5% chance of default is still far too high to attract project finance on normal or conventional terms. This indicates that an SMR can be a technologically mature, cost-competitive project and remain unbankable if it is forced to operate in an incompatible electricity market structure. In terms of finances, the learning curve has only a marginal benefit compared to the structural, transformative effects of a regulated revenue framework. This also serves to put a crucial brake on the techno-optimism typically imbued into discussions of SMRs suggesting that the engineering challenge of lowering costs cannot be dissociated from the financial architecture challenge of assigning risk. The quadrant analysis in Figure 4.12 provides a synthesised perspective on bankability by taking different scenarios' NPV and DSCR. Firstly, the chart emphasizes that a project's need to satisfy the different needs of two different capital providers, but equity investors expect a positive NPV and debt providers expect a low probability of default so they want a high DSCR that is consistently high across time.

The regulated scenarios reside comfortably in the top-right quadrant, indicating they are financially attractive to both groups of investors. The merchant scenarios fail on one or both dimensions. The Merchant/FOAK project has a negative NPV and has a median minimum DSCR below 1.0x making it unattractive. It is unclear whether the Merchant/NOAK project shows any potential for positive NPV in only the upper tail but it presents an unacceptably high risk to lenders. This dual-filter approach to bankability reinforces why projects with high revenue uncertainty struggle to be financed: even if a small chance of a high return exists for equity holders, the project will fail to proceed if it cannot secure the far larger tranche of debt capital required for its construction. The implications of the findings of this thesis are large and actionable for the key stakeholders looking to advance the deployment of SMRs. The main takeaway for governments, is that their function is not to "pick winners," or simply subsidise technology, but to provide a bankable market structure. The most effective and efficient policy lever for advancing SMR deployments is providing durable, long-term revenue stabilising mechanisms. Policies which more closely align with risk allocation such as Contracts for Difference (CfDs) or Regulated Asset Base (RAB) models, will be so much more powerful than grain upfront capital for providing access to private capital. Governments need to be aware of their crucial role in ensuring the industry has a pathway through the economic "valley of death". It is clear from the simulation that private capital will not fund the initial phase-high cost first-of-a-kind (FOAK) projects by itself, so the state needs to act as an anchor customer or a first-move risk taker, through either direct procurement or very extreme contract terms for the first tranche of projects, as occurred at Hinkley Point C. Policy certainty is key: nuclear has multi-decade investment horizons and thereby stability and credibility of policy will need to withstand many short-term political cycles.

The research in this thesis gives private sector participants in the SMR the evidence to confirm the models will need to treat them in a very different way to a standard power merchant play. They are, and will likely remain for the foreseeable future, a public-private partnership asset class, and investment strategies should thus focus not on speculating on future electricity prices, but rather on targeting geographic areas with credible, long-term policy support and creating projects that are specifically designed to align with these government frameworks. The developer's role is perhaps just as much about financial and regulatory engineering as nuclear engineering.

The DSCR analysis, from the perspective of finance institutions, is a clean pathway for understanding credit risk. Lending to a merchant SMR project particularly first of a kind (FOAK) unit is an untenable credit risk given the market conditions. However, when you have regulated structure, then the credit profile transforms into 'infinite space', where cashflow characteristic of the project is no more than a contracted infrastructure asset, or regulated utility, and thus a very attractive, low risk proposition for long term asset classes such as pensions and banks focused on infrastructure projects.

While this thesis provides a solid statistical framework as we can see, it also has limitations, which indicate potential areas of future academic research.

First, the model applies a base case and an overly simplistic approach to long-term electric price analysis, using a uniform distribution to capture general uncertainty. In the future, more sophisticated stochastic processes could be incorporated into the study, such as mean-reverting, occasionally jumping volatility clustering processes, to represent the multi-dimensional and complicated electricity market price dynamics of modern retail electricity markets, especially with high penetrations of intermittent renewables.

Second, the supply chain dynamics model have depended on a binary understanding of FOAK / NOAK cost and effort. An upgraded model would incorporate a dynamic learning rate function, such that price reductions could be explicitly identified and linked to cumulative number of units installed, both globally, or in a regionally based SME effort to narrate efforts on achieving target costs.

Third, the thesis focused only on the sale of electricity into the grid. An important potential market to limit for SMRs is providing firm power and heat into dedicated industrial customers, such as chemical plants, or such as energy-intensive data centres. Future research should model the bankability of SMRs underwritten by long-term corporate Power Purchase Agreements (PPAs). Such a structure would present a different risk profile, replacing wholesale market risk with corporate counterparty risk, and could represent a viable alternative financing path.

Ultimately, this analysis focused on a CfD as the representative regulated model. A useful follow-up to this research would be a comparative analysis that took on the model risk-sharing elements of the Regulated Asset Base (RAB) model that shares a portion of the construction risk with consumers in return for a lower cost of capital. Quantifying the relative costs and benefits of these two leading policy frameworks would provide invaluable guidance for governments.

The global intention to build a new generation of nuclear power led by the fact of Small Modular Reactors is at an inflection point. The technical potential is apparent and the strategic necessity is more widely accepted than it has been. Despite this, the result of SMRs will be based on finance decisions made in the offices of finance ministries, energy regulators, and institutional investors.

The challenge is clear: the economic profile of a nuclear power plant does not fit the risk profile of a liberalised energy market. The evidence presented from this research illustrates with quantitative rigor that a bridge must be built to accommodate this profile mismatch, and the bridge must be built by public policy. A blend of technological innovation with smart financial architecture is not optional, it is essential. This research has offered a strong grounding for understanding, and creating, this architectural context with empirical robustness for the important policy and investment decisions that will shape the future of nuclear energy in the twenty-first century.

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