Financing new nuclear in Sweden

14 May 2024

Building a better working world

Contents

Foreword

This EY report has been commissioned by the Confederation of Swedish Enterprise. Based on extensive interviews with more than 15 public and private sector organizations over a three-month period in early 2024, the report aims to share insights and conclusions on potential development pathways for newbuild nuclear investment in the Swedish market. Further it assesses if and how both sides of the market might come together to re-deploy nuclear energy at the required scale and pace. These are a few selected highlights from the study:

- The government has announced ambitions to build at least 2.5 GW of new nuclear generation by 2035 and 10 GW by 2045.
- Program-level success, matching the scale of Sweden's announced policy targets, benefits from a holistic, fleet-based approach for the nuclear industry.
- Policy clarity is essential to create a stable investment climate for new nuclear, but key details and instruments need to come in place.
- A comprehensive government support package needs to be considered.
- Sweden has multiple pathways to achieve least-cost nuclear generation.

The interview responses have been anonymized and attributed by category to provide insights into how different market sectors view the challenge of attracting investment in support of Sweden's nuclear newbuild targets.

The report presents the EY organization's findings and sets out an investment and development framework for Swedish nuclear newbuild consistent with the views of several interviewees.
The findings and conclusions in the report reflect the extensive interview process and research conducted by EY teams, and do not necessarily reflect the institutional views of the EY organization or the Swedish Enterprise.

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All images of Oskarshamn and Forsmark power plants used by courtesy of Vattenfall and Uniper Sweden.

1 Introduction

The purpose of this report is to inform and support the decision-making required by Sweden AB for the government to deliver its recently announced newbuild nuclear energy targets. The Confederation of Swedish Enterprise (Svenskt Näringsliv, Swedish Enterprise) believe that for nuclear energy to be sustainably re-deployed at scale in Sweden, special attention should be paid to how the costs, risks and benefits of the nuclear investment program are shared across the constituents of the Swedish energy market. Although Sweden and other highly liberalized energy markets seek private sector investment, the nuclear newbuild market has historically faced challenges in attracting private capital for reasons inherent to the nature of the technology and power market design. Based on interviews with Swedish Enterprise's members with an interest in nuclear energy, this report identifies and explores the investment design criteria and process by which the value of nuclear energy in the Swedish market can be unlocked.

Nuclear energy has been said to have forged over the years a "viable delivery technology", namely, large pressurized light water reactors that meet stringent, ever-rising standards for safety and security, permitting, grid connection, industrial-scale offtake, public acceptance, etc. but "not a business model". The premise of this report was to have a series of structured conversations with the Swedish nuclear energy community and its main stakeholders, to test limits in the individual components of the business model in a way that might achieve economic equilibrium in a market context. The report asks, how can the technical merits of nuclear generation be brought into alignment with the commercial and financial return requirements of the market in a way that facilitates timely final investment decisions (FID) for newbuild projects?

The interviews prioritized Sweden's main power sector stakeholders, focusing on the success factors and pre-requisites for attracting private sector investment into nuclear power plants and infrastructure. Based on extensive dialogue with nuclear practitioners and business leaders, the report identifies preliminary considerations for long-term program-level mobilization in the market. The report considers project-level investment pre-requisites and sets out a composite view for government policymakers of the enablers for Sweden's nuclear targets. Swedish Enterprise represents some 60,000 companies, 48 sector- and employer organizations and over two million employed.

This report draws out the enablers for investment, recognizing nevertheless that a nuclear newbuild program is much more than commercial or financial risks and rewards. Finance is a result of the collective decisions and undertakings made upstream of FID. Finance and financeability are an outcome, not an input. Accordingly, in line with the structure of the interviews, this report breaks down the path to FID into its constituent parts and assesses the compatibility of each component with the Swedish market context.

Based on feedback from the interviews, and the EY organization's global nuclear experience, the report presents a matrix of range-bound factors that drive nuclear FID, and suitability levels likely to be most consistent with the Swedish context. These investment factors: delivery model, operating model, revenue model, financing model, etc. can be applied across the full range of technological options potentially available for deployment in Sweden over the 2035 to 2045 policy timeframe. Altogether, for nuclear policy success, the investment factors will need to come together to form, in time, the most compelling investment model possible for Swedish nuclear. The International Atomic Energy Agency (IAEA) has developed guidelines for the successful implementation and delivery of nuclear newbuild programs and projects. The guidelines cover 19 "nuclear infrastructure issues" comprising the full lifecycle, from early development to project delivery related activities, to operations and shut-down or decommissioning, see figure 1.1. This framework identifies some of the most critical issues for the development of nuclear power plants, including both large and small modular reactors.

Figure 1.1: IAEA guideline for member states identifying 19 issues for nuclear newbuild programs[1]

These nuclear infrastructure issues highlight the complexity and multifaceted approach needed successfully to develop nuclear power plants, even in "recomer" (or first-in-a-while) markets such as Sweden. The past 20 years of nuclear development across Europe have been instructive in this regard. Though a handful of newbuild projects have progressed and are meeting (or have already met) their essential technical milestones (licensing, permitting, construction start and completion, fuel loading, commissioning and commercial operations), there is limited public evidence that any project will have met its originally-declared non-technical objectives (being cost, schedule, returns, taxpayer costs or benefits, etc).

The urgency of the European energy trilemma (referring to energy that is clean, resilient and affordable) has come to the fore over the past months at the COP28 (by now known as the "nuclear COP"), the inaugural Nuclear Energy Summit in Brussels and in mainstream public opinion worldwide. Increasingly, the focus of public debate has shifted from the "what," i.e., the gradual realization that more nuclear is needed in the global energy mix, to the "how."[2] Numerous interviewees agreed with the statement that nuclear financing may be the longest lead item in any commercial nuclear project or program. Most also agreed with the external challenge that, in the current policy context, "nuclear is too slow and too expensive"[3].

Recognizing the dynamic nature of markets and the typically long lead times to achieve FID in nuclear energy development, the report presents a framework that would help efficiently organize widely-available resources (being essentially people and their time, some of their money and a lot of other people's money, in trust) to develop investable proposals and compress schedules to avoid slippage of target FID dates. This requires a process by which non-technical program and project definition (government policies and instruments, industry vision and tools, business plan, financial model, risk matrix, etc.) can mature in line with the technical definition (unit costs, schedule, performance, etc). The framework that emerges from the interviews and that is presented in this report is proposed as a potential starting point for what could become, in time, a contemporary Swedish nuclear development model.

The conclusion of this report reflects arguments and presents options for an indicative Swedish nuclear investment model at FID, but the primary innovation would be the introduction of a development model, an incentivized organizational framework whose principal objective would be to set out deliverable investment proposals. The report's conclusions capture practical recommendations for policy- and decision-makers that would help drive broad-based interest in nuclear energy development and raise confidence among commercia players and the financial community along what has been historically an unpredictable path to FID.

Sweden is not the only country in Europe with an ambition to develop an offering of investable nuclear newbuild capacity. But the highly price-sensitive, fragmented nature of its

1 Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy (NE) Series No. NG-G.3.1 (Rev. 2)
2 Outcome of the first global stocktake. Draft decision -/CMA.5. Proposal by the President, 28th paragraph, UN Climate Change Conference – United Arab Emirates Nov/Dec 2023
3 Nuclear energy too slow, too expensive to save climate: Dunai & De Clercq, Reuters, September 24 2019

electricity market may necessitate technology decisions (for any given state of readiness and deployability) being divorced from financing decisions. A technology- and design-neutral development and investment model would ensure the highest levels of technical and commercial innovation.

In 2024, the Swedish market is in a strong position to benefit from the lessons learned of recent projects to achieve timely FID and deliver against the declared commercial and financial objectives.

The success of a nuclear newbuild program will require sustained mobilization of market resources, both in Sweden and internationally. Achieving the scale required by Swedish energy policy will be contingent upon the reactivation, development and participation of the full nuclear energy value chain, from technology and delivery, to plant operations, regulatory oversight, power trading and consumption, transmission infrastructure, finance (equity and debt), education and public policy. Accordingly, interviews have been conducted with entities representing the different segments of nuclear vendors, supply chain partners, owner-operators, investors, consumers, and government representatives, see figure 1.2. Several other segments related to but not directly in scope of the financial focus of this report have not been included in the list, including research institutes, government agencies such as the Swedish Radiation Authority (SSM) and Swedish Contingencies Agency (MSB), the transmission grid owner Svenska kraftnät (Svk) and municipalities. The responses and insights from the interviews have been anonymised and presented as viewpoints for one or several segments rather than attributed to a single person or entity. To illustrate viewpoints from different sectors, quotes from the interviews will appear as boxes throughout the report, where useful insights have been deemed representative of the views of certain segments, see the example on this page.

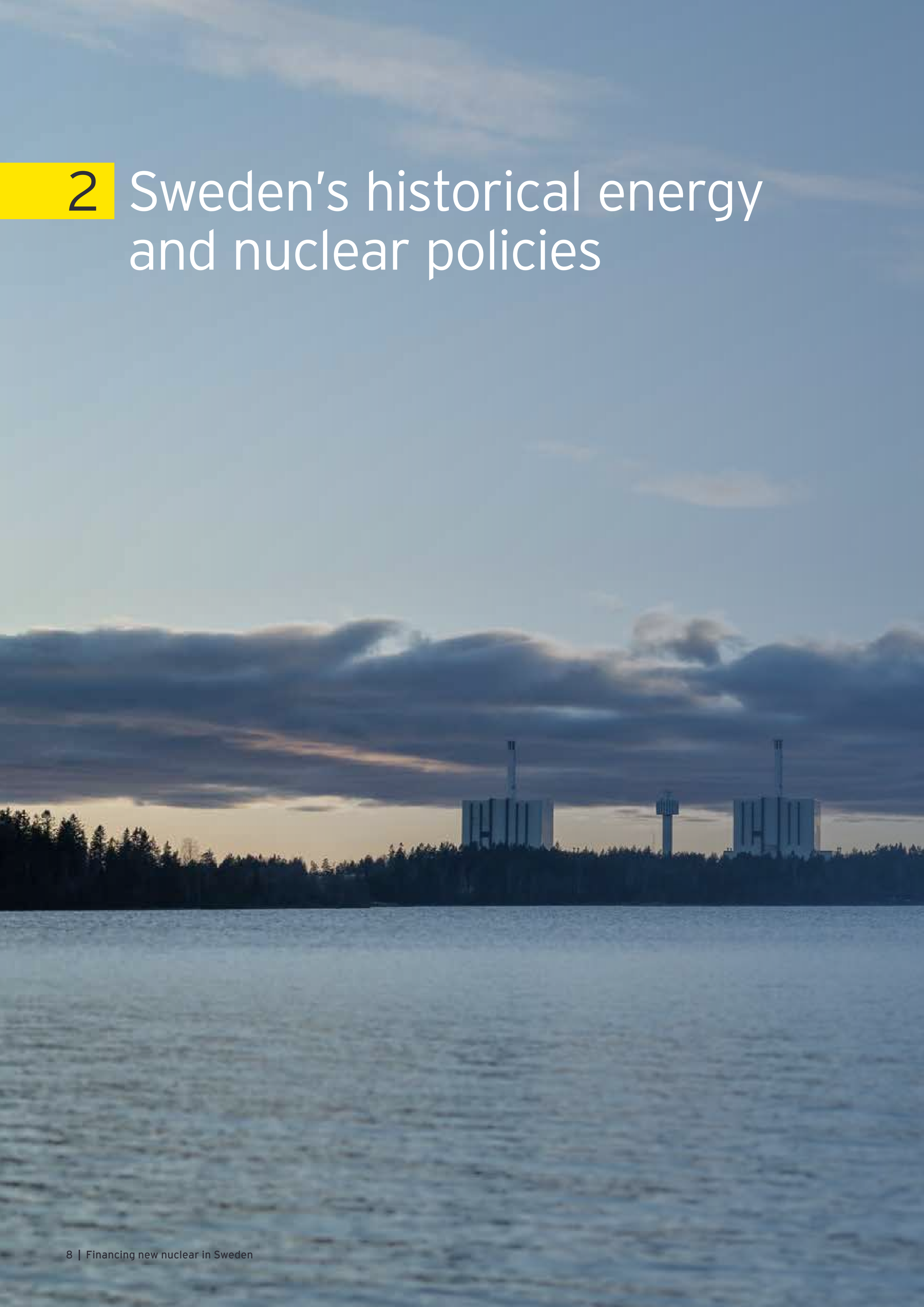
> “
> It is indeed necessary to learn from one's mistakes;
> but it is better to learn from others' mistakes.
>
> **Owner-operator interviewee**

> “
> Credit guarantees cover financing and credit risk, not market and project risks,
> which are more significant and not yet well understood.
>
> **Financial interviewee**

Owner or operators	Finalcial institutions	Industry	Vendors	Enablers or facilitators	Government
Vattenfall	SEB	NCC	EDF	Energiföretagen	Regeringskansliet
Uniper	Länsförsäkringar	Boliden	Hitachi	Kärnfull Next	
Fortum	Skandia	SSAB	Rolls Royce	INBEx	

Figure 1.2: Contributing entities with insights and findings in this report.

2 Sweden's historical energy and nuclear policies



The Swedish economy is characterized by energy-intensiveness[4] and growth policies predicated upon a doubling of electricity demand from current levels (annual demand of 134 TWh in 2023) to 345 TWh by 2050[5], making electricity exports an important source of additional revenue[6]

The development of Sweden's energy market from 1970 onwards can be described in several distinct phases as shown in figure 2.1, characterized by key political decisions, advancements in technology, and evolving societal attitudes towards energy consumption and environmental protection.

1970-1980	1980-1990	1990-2000	2000-
Nuclear era	Energy debate	Market liberalization	Renewable and climate goals

Figure 2.1: Timeline of Sweden's key precedent energy policies

2.1 Sweden's key precedent energy policies

The 1970s: nuclear era

Prior to the 1970s, Sweden's energy production was primarily based on hydropower and oil-fired power plants. Following the global energy crisis sparked by the oil embargo in 1973, Sweden began to diversify its energy portfolio. Nuclear energy was seen as a way of reducing the dependency on imported fuels, whose price and volume became increasingly subject to geo-political shocks, and of complementing hydropower, whose capacities were constrained. After extensive construction efforts throughout the decade, 12 nuclear reactors were operational or under construction and nuclear energy was generating a significant proportion of Sweden's electricity (~40%). The construction and operation of the nuclear reactors was possible through the establishment of a competent regulator, a strong supply chain, extensive nationwide nuclear skills, suitable owner or operators and strong public acceptance.

The 1980s: the energy debate

The accident at the Three Mile Island nuclear power plant in the US in 1979 caused worldwide concern about the safety of nuclear energy. This was a contributing factor leading to a referendum in Sweden in 1980, in which the people voted in favour of a policy to phase out nuclear energy by 2010. While not legally binding, this referendum shaped Sweden's energy policy for the next decade and significantly delayed the commissioning of the reactors Forsmark 3 and Oskarshamn 3 to August 1985.

The 1990s: market liberalization

The first bill to deregulate the Swedish electricity market was proposed by the government in 1993 with the intent to "achieve a more rational use of resources.[7]" Sweden undertook a significant reform, gradually shifting from a monopolistic structure to a competitive market. This

4 IEA statistics 2023
5 Långsiktig marknadsanalys, Scenarier för kraftsystemets utveckling fram till 2050, Ärende nr: 2023/4164, Svenska kraftnät
6 Swedish Energy Agency (2023). Energy in Sweden – Facts and figures 2023
7 Handel med el i konkurrens, Proposition 1993/94:162, Regeringens proposition, 1993

allowed consumers to freely choose their electricity supplier, increased competition in the market, and provided more efficient pricing. The Nord Pool Spot market, where production and consumption of electricity are traded, was also established, enhancing cross-border electricity trade throughout the Nordic region.

In Nord Pool and other markets where prices were set on a "system marginal price" basis, nuclear power plants became market price takers. Nuclear energy generation cashflows became dependent on commodity price cycles of natural gas, coal and oil as well as weather patterns due to the rise of wind and solar power.

2000 until today: introduction of renewables and climate goals

With growing global concerns about climate change and its impacts, Sweden started focusing on the transition to renewable energy sources. Policies were put forth to support renewable energy deployment, particularly wind power. An example is green certificates that were introduced 2003 to the market as a subsidy to create further incentives to construct renewable energy production.

The target of phasing out nuclear energy was repealed in 2009 due to recognition of its role in providing a stable, low-carbon power source. The focus instead shifted to maintaining and upgrading existing nuclear power plants. In 2015, Sweden pledged to achieve net-zero greenhouse gas emissions by 2045. A cross-party agreement in 2016 set target of 100% renewable electricity generation by 2040, which was changed to fossil-free generation in 2022.

With the comparative advantage of fossil-free electricity at low cost industries based in Sweden could start implementing electrification of hard to abate processes in line with directives such as the Corporate Sustainability Reporting Directive (CSRD) requirements. Low total cost of energy has also enabled these companies to gain vital experience in decarbonization and attract investments into green technology.

Today and looking ahead — a fossil-free future

Currently, Sweden boasts a diverse and largely fossil-free electricity mix comprised of nuclear, hydro, wind and a small but growing contribution from solar power. Sweden, like other European Union (EU) and Organization for Economic Cooperation and Development (OECD) markets, benefitted from sharply decreasing installation costs for renewable energy for an extended more than 20 years of period. Together with decreasing nominal and real discount rates for renewable, the Swedish end users benefitted from an exceptional but unsustainable consumer windfall. When renewable power penetration levels became high (from a grid and broader system cost perspective), the interest rate cycle troughed and began a sharp rise and global supply chains became structurally bottle-necked, the Swedish energy mix (as in many other OECD markets) became unpredictable and exhibited large fluctuations in the electricity price.

2.2 Sweden's electricity system and readiness for a nuclear expansion

The Swedish electricity market, which is today deregulated, was prior to the liberalization reform dominated by state- and municipality-owned utilities. The deregulation took place in 1996 and effectively ended former monopolies, opening the door to competition in the market where possible. Sweden's electricity market now operates under a deregulated system, allowing for competitive influence and a range of choices for consumers. Similarly, to most EU countries, consumers are incentivized to compare suppliers based on their marginal cost of generation, rather than system costs. Accordingly, due to strong investment in renewable and other intermittent energy capacities, Sweden has witnessed steady declines in marginal costs of generation together with rising system costs.

Sweden's electricity supply chain, which is largely low carbon based, is structured to enable large existing capacity of baseload nuclear energy to be generated and dispatched to the national grid. The basis is a general flow from generation through transmission to consumption. As new technologies have become available and the share of intermittent electricity generation has increased, additional components have been added. Figure 2.2 provides an introduction of the key energy blocks of the current Swedish electricity system.

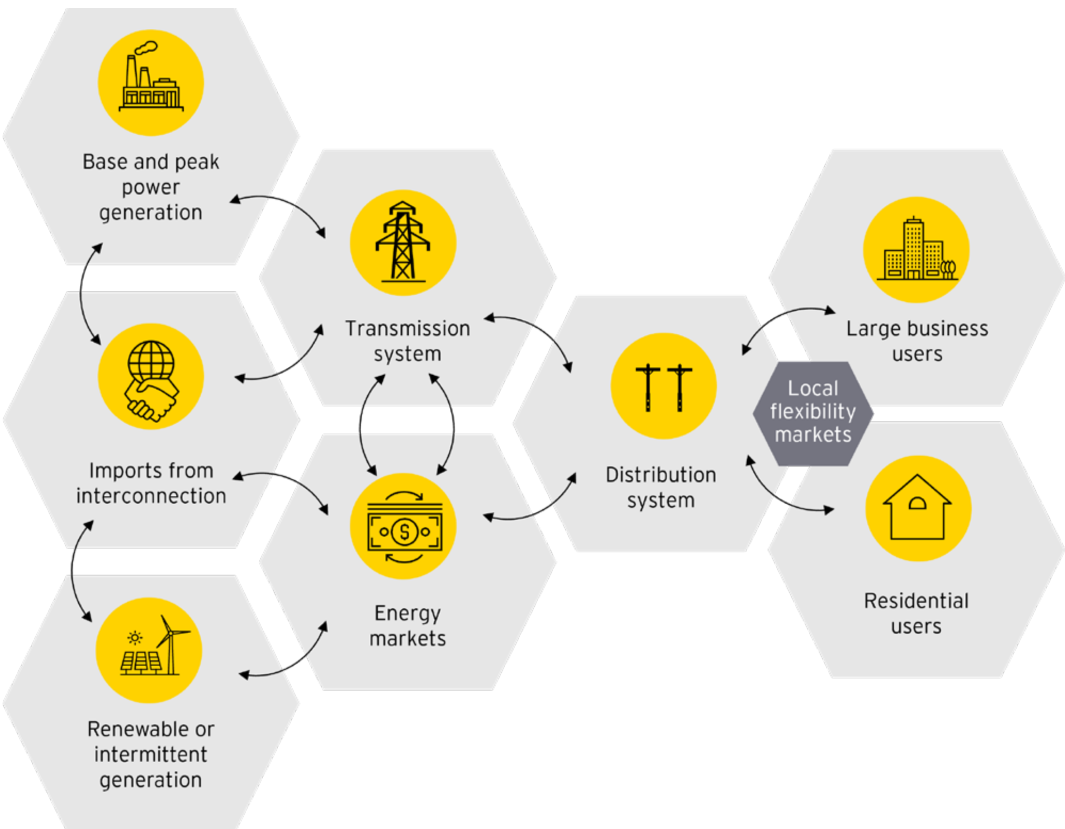


Figure 2.2: Overview of a simplified electricity system with base and intermittent generation, transmission grid, distribution grid and end consumers

> Capacity factor on the TSO-level can guide how to expand the electricity system and should be put into market requirements.
>
> **Government representatives**

> The market needs to develop where access to the grid can be given to new users at the right point and with the right function.
>
> **Government representatives**

Annually published statistic from the Swedish energy authority shows electricity production in Sweden drawing mostly from hydro (40%), nuclear (30%), wind power (20%), bioenergy (10%) and solar (1%)[3]. Most generation assets are in the north of the country, hydroelectric plants and wind turbines, while the nuclear power plants were strategically placed in the south to balance the power system. In recent years, the contribution of wind power has increased significantly while nuclear energy capacity has decreased due to the closure of four reactors in the last decade. The transmission of electricity throughout Sweden falls under the responsibility of Svenska kraftnät, the authority that operates the national grid as the transmission system operator (TSO).

The distribution, involving the regional and local transportation of electricity, is managed by several regional and local network operators. Consumers can choose their electricity supplier, but cannot choose their distribution network operator and the market remains regulated. As new capacity comes online and is fed to the transmission grid, the distribution grids will also need to build out capacity in areas where low-carbon industries are located. Sweden has a competitive electricity market where consumers can choose their electricity supplier based on competitive pricing, environmental impact, contract terms, or other preferences. This has led to a wide array of suppliers ranging from large multinational corporations to small local suppliers. The primary power exchange in the region is Nord Pool, which also includes several other countries in the Nordics and Baltics. The market offers a marketplace for buying and selling electricity and coordinates the production and consumption of electricity across multiple countries.

Regulatory oversight of the electricity market is carried out by the Swedish Energy Markets Inspectorate (Ei). It monitors the functioning of the electricity market, supervises electricity network operations and ensures that they are run efficiently as well as sets the revenue frameworks for network operations and handles consumer complaints and disputes.

The Swedish electricity market is divided into four price zones, from SE1 in northern Sweden to SE4 in southern Sweden. The zones are connected through the transmission grid, but electricity prices differ between the zones. The price zones were introduced in 2011 to incentivize construction of additional capacity in the south of Sweden by making market conditions more favourable.

Overall, Sweden's electricity market is characterized by a mix of market principles and regulatory measures, with a clear focus on ensuring, e.g., secure, fossil-free and affordable energy for all consumers. Nuclear energy can contribute to sustain the above principles, and the domestic industry has started to acknowledge this, expressing their willingness to invest directly into nuclear energy. Companies within heavy industry like mining, vehicle manufacturing, construction, battery production, steel and biomass processing are planning on the electrification of their manufacturing processes to decarbonize the value chain.

2.3 Development and structure of the Swedish nuclear energy program

The first commercial-scale nuclear power plant in Sweden, Oskarshamn 1, was ordered in 1965 and construction started in 1966. This was the starting point of a period of continued nuclear energy development over the next two decades, characterized by the construction of 12 reactors at four different sites across Sweden, see figure 2.3.

The nuclear energy phase-out policy based on the 1980 referendum was not fully implemented. In 1991 the government permitted the lifetime extension of nuclear power plants and later, in 2005, the replacement of existing reactors. By 2010, the Swedish parliament made a significant decision to repeal the ban on the construction of new nuclear reactors.

In 2000 the "output taxation," an excise duty based on the thermal effect of the reactors was introduced. Increases of the tax throughout the first decade of the century reduced the profitability of the industry. Vattenfall, in 2016, stated that based on existing policies, all nuclear reactors were at risk for premature closure. The duty was lifted in 2018. The current inventory of nuclear power plants and related facilities can be found in figure 2.4.

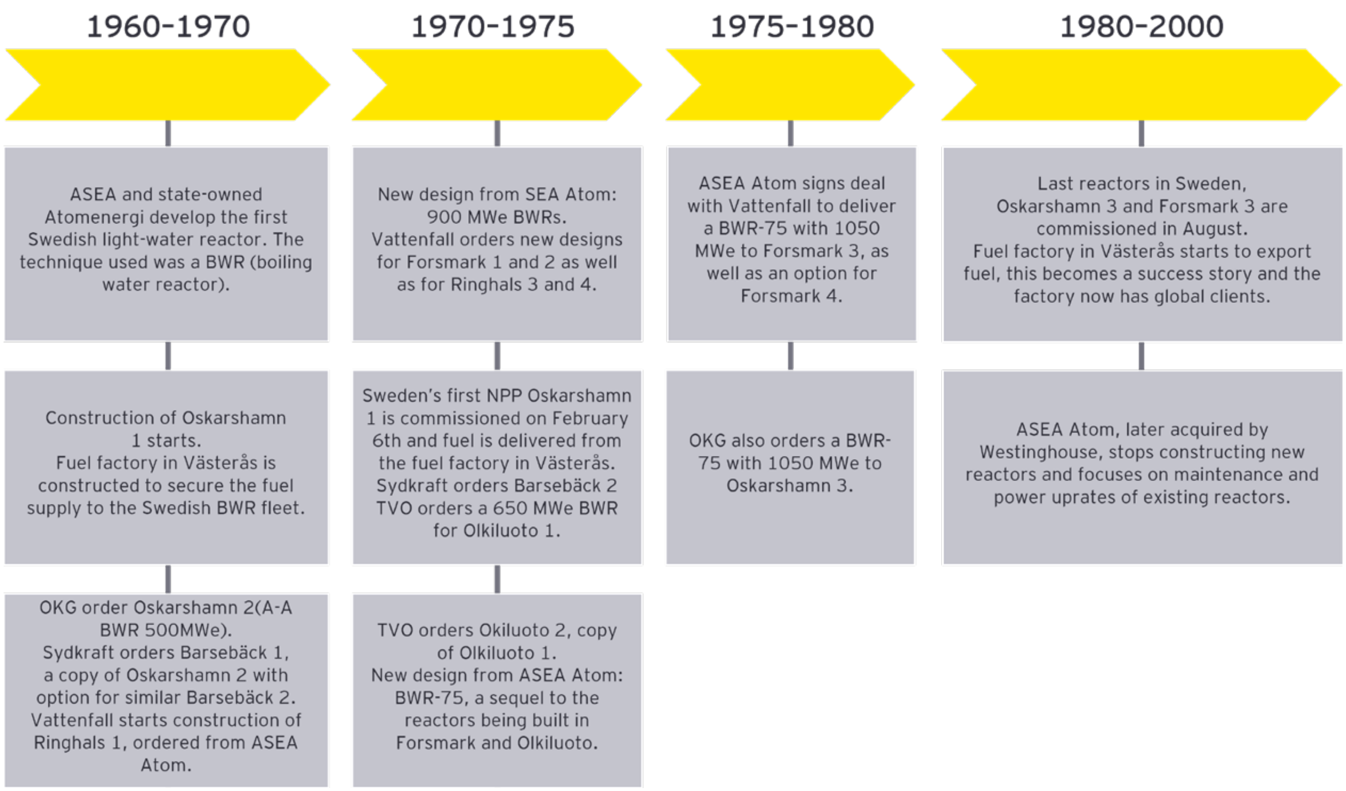


Figure 2.3: Sweden's nuclear capability development with newbuild and uprates

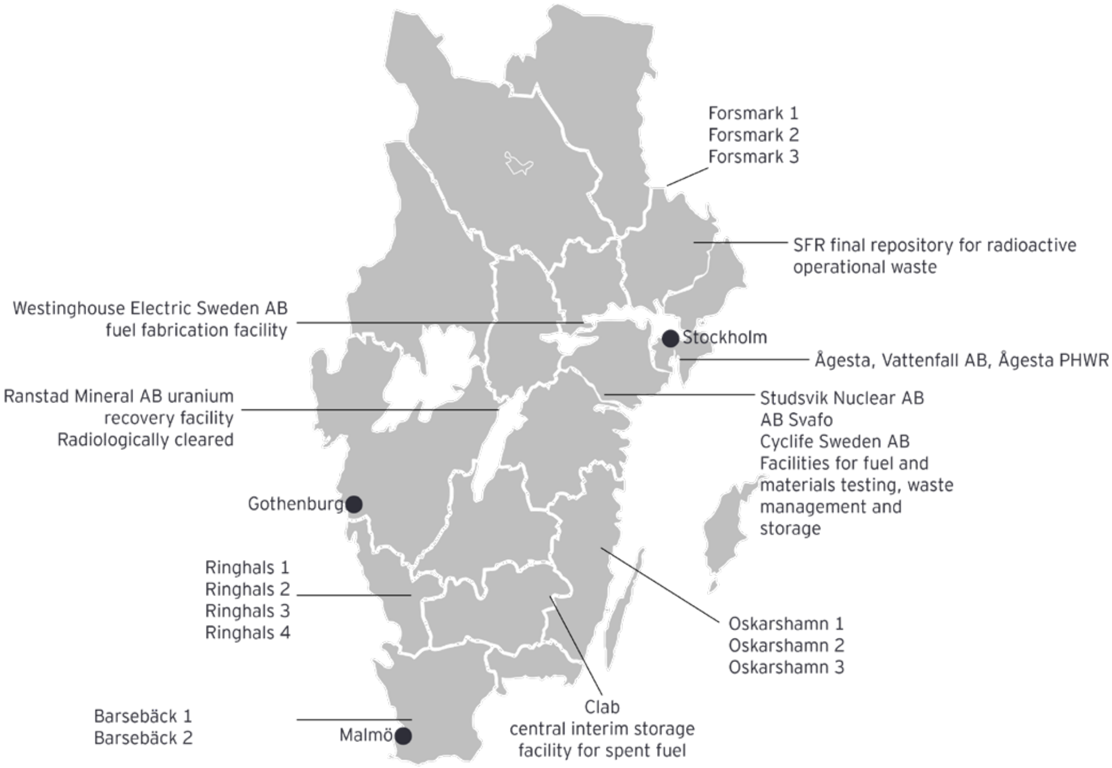


Figure 2.4: Sweden's nuclear power generation landscape[8]

Financing of Swedish nuclear

The financing of nuclear power plants in Sweden has historically been arranged with a part of contribution from public funding. Initially, the Swedish State Power Board, now Vattenfall, played a role in financing the construction of nuclear power plants. As a state-owned entity, it was able to secure funding from the national budget. The projected and outturn costs of constructing the plants was also factored into the price of electricity sold to consumers. Despite significant cost overruns at the inaugural plant, Ringhals 1, taking a full life cycle view of the unit, Vattenfall was able to assure completion funding with confidence in the profitability of the plant.

Other financing has also been utilised with municipalities and affiliated companies, such as Sydkraft, investing in and operating nuclear power plants under current ownership of Uniper, having invested their own resources in the construction of the Oskarshamn nuclear power plant.

Additional funding and financing methods were introduced to cover for the nuclear lifecycle costs. For instance, nuclear operators are required to pay fees into the nuclear waste fund, which is used to manage and dispose of radioactive waste.

Plant uprates and license renewals

In Sweden, there have been consistent efforts towards uprating nuclear power plants to enhance their operational efficiency and lifespan. All plants today operate at a higher power level compared to what they were originally operated at. Below are examples of uprates.

8 Sweden's ninth national report under the Convention on Nuclear Safety – Regeringen.se

> “
> The current plants are scheduled for lifetime extensions with a similar timeline as the nuclear newbuild. This creates a challenge to have enough people with expertise. This is relevant both in Sweden and Sweden in competition with other countries.
>
> **Owner/operator interviewee**

Oskarshamn nuclear power plant: Between 2009 and 2012, Oskarshamn 3 reactor was uprated from its original capacity of 1,200 MWe to 1,450 MWe, marking the largest power increase for a single reactor in Sweden. The uprate was a result of significant modifications, including a new turbine and main generator, condenser and transformer as well as several safety upgrades.[9]

Forsmark nuclear power plant: Between 2005 and 2007, Forsmark 1 and 2 were uprated by approximately 10%, while reactor 3 was uprated by around 12%. Further power upgrades were performed later, most recently in 2022.

Ringhals nuclear power plant: Between 2006 and 2015, Ringhals plant saw an increase in power output from reactors 3 and 4 by implementing turbine upgrades and changing operational strategies.

Importantly, all these uprates were subject to extensive review and approval from the Swedish Radiation Safety Authority (SKB), following a rigorous safety analysis, to ensure that an increase in power does not compromise safety. Power uprates like these are the closest the Swedish nuclear market has come to investments in newbuild during the last three decades.

Nuclear waste management

Sweden has detailed procedures for the safe and permanent disposal of nuclear waste in accordance with best international practice. The timeline for spent fuel goes from spent fuel cooldown to interim storage facility called Clab (central interim storage facility for spent nuclear fuel) and then to final repository method called KBS-3 at the spent fuel repository.

Nuclear operators in Sweden are required by law to pay fees into the nuclear waste fund, which is independently managed by the Swedish nuclear fuel and waste management company. The fees are calculated based on the amount of electricity generated, ensuring the companies take financial responsibility for the waste they produce on a full life-cycle basis.

Key takeaways on development and structure of the Swedish nuclear energy program:

- Sweden existing fleet of nuclear power plants was financed, directly and indirectly, by the government to a large extent. Development of previous reactors was undertaken under regulated market where government had a natural monopoly and role to finance critical infrastructure.
- Uprates have helped to compensate for the loss of power from the early decommissioning of a few nuclear power plants. Owners and operators have already optimized existing capacity with uprates of existing large reactors, however existing reactors can be operated beyond their current regulatory licensing period via lifetime extension or extended long-term operations (extended LTO).
- Swedish cost model includes a contribution to the handling of radioactive waste, similarly to other OECD markets. Nuclear redeployment offers the opportunity to reinvest in closing the fuel cycle, as well as in solutions for final disposal or repository. Current capacities in the country may need to be further developed to accommodate an increase in volumes at the back-end of the fuel and plant lifecycle.

9 Full power for uprated Oskarshamn 3, World Nuclear News, September 26 2011

2.4 Sweden's current nuclear energy supply chain

During Sweden's nuclear build out in the 1970s and 1980s, a unique supply chain was created in the country. Several interviewees highlighted the capability and competence that was built in Sweden during these decades and that Sweden's knowledge was at a high level during this period.

The current nuclear eco-system contains several components that makes Sweden a "first-in-a-while" or "recomer" country for nuclear newbuild rather than "first-of-a-kind" (FOAK) or "newcomer" country. While the necessary competencies and companies currently exist in a limited capacity, their historical foundation and the ability to scale suggest that mobilizing for newbuild projects will be more efficient, thereby shortening the lead time compared to first-of-a-kind initiatives. A local supply chain has the benefits of operating according to current industry practices, labor laws and collective agreements. Using existing subsuppliers in the early stages and can facilitate and support the introduction of foreign companies to the sites. Even if the first projects start with a large portion of foreign contribution, the long-term supply chain for the program can pivot to more local content as the program progresses. The situation is similar for the non-nuclear supply chain where more local content is also ensuring reduced dependence on global souring.

"

Sweden needs to build the supply chain, blue collar workers, manpower, competition increasing from many countries building at the same time. First units will be focusing on building up a competent supply chain. Sweden can build the supply chain together with Finland, especially if we build using the same technology.

Enabler and owner and operator interviewees

"

Sweden as a country should invest in factories as they are an investment, derisking the program and creating highly qualified jobs. Fund through grant or risk sharing mechanism.

Vendor interviewee

"

With all nuclear newbuild activities in Europe, a national supply chain is not necessary. Many skilled workers and suppliers can be sourced internationally.

Owner-operator interviewee

"

Cultural differences among subsuppliers have been known to be an issue. Best chance to get it built is to use the supply chain of the vendor. New nuclear countries have staggered approach. For the first plant 90% international, 10% domestic, next 50-50, next 20-80 and so on.

Enabler interviewee

When the first nuclear plants were built in Sweden, Asea Atom was both the designer and constructor of the boiling-water reactor (BWR) while Westinghouse Electric built the three pressurized-water reactors (PWR) at Ringhals nuclear power plant. The original vendor, Asea Atom, has since been acquired by Westinghouse, making the latter the original equipment manufacturer (OEM) of nuclear power plants in Sweden.

Today, local fuel manufacturing is provided by Westinghouse and Studsvik. The Westinghouse factory is providing fuel to reactors across Europe. Studsvik, originating from the research institute that designed Sweden's first reactors, is a company specializing in materials testing and nuclear fuel investigations. While its materials testing reactors are now closed, the company continues to operate its own hot cell laboratory for fuel investigations. The company also provides decommissioning and waste treatment services. Furthermore, the company provides engineering services and fuel and reactor management software.

The three owners and operators of nuclear power plants in Sweden are Vattenfall, Uniper Sweden and Fortum, each with its own characteristics and assets. Vattenfall is the majority owner and operator of the nuclear power plants at Ringhals and Forsmark. Uniper Sweden is the majority owner and operator of Oskarshamn nuclear power plant and minority owner in Forsmark, Ringhals and Barsebäck. Fortum, on the other hand, is minority owner in Oskarshamn and Forsmark nuclear power plants.

Swedish Radiation Authority (SSM) is the regulatory authority responsible for radiation safety in Sweden. SSM has mandate from the Swedish government within the areas of nuclear safety, radiation protection, security and nuclear non-proliferation. Its operations are guided by Sweden's Radiation Protection Act and the Act on Nuclear Activities, among other national and international laws and conventions.

Svensk Kärnbränslehantering AB (SKB) is owned by Vattenfall, OKG AB, Forsmark Kraftgrupp AB and Sydkraft

> Private investors can be involved in both equity and debt, but only as minority stakeholders. This has material implications for capital structuring and ring-fencing of their risk and reward position.
>
> **Financial institutes interviewee**

> If there is a risk of losing money with volatility in returns, the business case needs to address risk and return compared to investing in capital markets.
>
> **Financial institutes interviewee**

Nuclear Power AB. SKB is tasked to manage all spent nuclear fuel and nuclear waste from the nuclear power program. SKB owns and operates the Äspö Hard Rock Laboratory and the canister laboratory at Oskarshamn. SKB is also the licensee for Clab at the Oskarshamn site and the disposal facility for short-lived operational radioactive waste (SFR) at Forsmark. The government, on 22 December 2021, decided to grant a license for the extension and continued operation of SFR to accommodate also decommissioning waste. Also, the government, on 27 January 2022, decided to grant SKB a license to construct, possess and operate a disposal facility for spent nuclear fuel.

The Nuclear Training and Safety Centre (KSU) serves nuclear power plants in Sweden and provides training for control room operators, including simulator training. KSU also provides training for maintenance personnel and general technical training for workers in the nuclear industry. Furthermore, KSU analyzes national and international operational experience to support the Swedish nuclear power plants.

Svenska kraftnät is an authority that is operated in the form of a state-owned enterprise. One of their responsibilities is to maintain the national grid in Sweden.

Non-nuclear supply chain

For auxiliary equipment, the remaining competence in Sweden relates to nuclear power. Sweden can provide grid technology, electrification products, automation products, gas turbines and advanced engineering materials, especially high-performance alloys and stainless steels as well as fluid handling solutions etc.. In addition, Sweden has several infrastructure companies that can play a role in infrastructure development, from constructing plant buildings, roads and transport facilities to managing utility infrastructure and detailed groundwork. The experience in large-scale projects and in the current decommissioning activities is an asset in ensuring the successful execution of nuclear newbuild projects. While not all are currently engaged in nuclear energy activities, these entities hold local knowledge and production capabilities, making them potential contributors to nuclear power plant construction and operation. For financial institutions in Sweden looking to invest in nuclear newbuild, additional risks are introduced. The EU taxonomy, however, has provided a framework to classify sustainable economic activities, allowing these institutions to engage in carbon-neutral and fossil-free projects more confidently.

Key takeaways on Sweden's current nuclear energy supply chain:

- Sweden has the advantage of being a "first-in-a-while" or "recomer" country in nuclear development with an existing nuclear ecosystem including e.g., power producers, nuclear competency and regulators.
- Activation of the supply chains will be a key activity for international vendors where the local content will increase over time.

3 Sweden's nuclear ambitions

September 2023 marked an important transition for the Swedish energy sector, with an announcement from the government to expand the country-wide nuclear energy capacity.

The announcement was followed by Sweden's parliament approval on a bill coming into force first of January 2024 that will clear the way for new nuclear power in the country by removing the current limit on the number of nuclear reactors in operation, as well as allowing reactors to be built on new sites[10].

Further, the government announced plans to construct the equivalent of two large-scale reactors by 2035 and a target of 10 GW new nuclear capacity in place by 2045[11].

3.1 Announced nuclear ambitions

Sweden has a target of net zero-emissions by 2045. That target is a key driver for the electrification of industry and transportation and the increased use of fossil-free electricity including nuclear. It is moreover projected that Sweden's electricity system will witness a doubling of its capacity in the forthcoming 20-25 years, whereby analysis conducted by Swedish Enterprise[12] shows that the most cost-effective combination encompasses wind, hydro, and nuclear power. The importance of a secure, stable and fossil-free power production at a societal level cannot be understated as it is a pre-condition for growth. Most of the anticipated and predicted decarbonization of Swedish industrial production processes, as well as the projected industrial growth rely on access to fossil-free electricity. Nevertheless, the growth potential for hydropower remains relatively limited, thereby amplifying the necessity for an extensive expansion of wind and nuclear energy sources. In their latest long-term market assessment, Svk projects an increased electricity demand that could reach at least 345 TWh by 2050[13] and sees a need for extensive expansion of new nuclear power, wind farms, and solar parks.

As a larger amount of weather-dependent electricity production is being integrated into electricity systems, the question of securing a predictable baseload power source becomes increasingly important.

Policy changes since September 2022

The Swedish government announced in the Tidö agreement that it would be taking a first step towards new nuclear energy production in the country, based on their commitment to ensure energy security, reducing greenhouse gas emissions, as well as maintaining a stable and efficient power supply for Swedish citizens. Furthermore, the government has proposed lifting the restriction that only allows new reactors to replace permanently shut down ones. It also suggests that new reactors could be built in locations other than existing reactor sites. This means that new reactors can be built both in new locations and at existing facilities, and new players can enter the market. These changes have material implications for the Swedish investment environment, from updating enabling legislation on siting and permitting, to regulatory updates and clarifications, to transmission system impact studies, to back-end capacity planning and human capacity building with respect to both nuclear skills and skills for nuclear.

10 Swedish nuclear bill passed by parliament, World Nuclear News, November 30 2023
11 Färdplan för ny kärnkraft i Sverige, Swedish Government, November 16 2023
12 Kraftsamling Elförsörjning, Svenskt Näringsliv, 2022
13 Långsiktig marknadsanalys, Scenarier för kraftsystemets utveckling fram till 2050, Ärende nr: 2023/4164, Svenska kraftnät

Separate special investigators have been appointed to improve conditions for the electricity system in general and nuclear specifically.

- National nuclear coordinator with the task to monitor and analyze the speed of progress in nuclear newbuild projects and identify additional actions to keep progressing
- Electricity market investigator to lead an investigation on how the future electricity market can contribute to a strong and reliable electricity system
- Investigator with the responsibility for looking into models for financing of new nuclear reactors
- Investigator with the responsibility to improve conditions for permitting and licensing of new nuclear reactors

However, the nuclear energy program, as it stands today, would benefit from clarity on how to achieve the planned expansion. As a first-in-a-while country, Sweden possesses a wealth of experience and players that could support the increased role of nuclear energy in the electricity system. The Swedish government has outlined that it intends to build 10 GW of new nuclear capacity by 2045, but not specified what kind of technology choices will be made to reach that goal. There are multiple avenues to increasing nuclear energy from the current 52 TWh that it represented in 2022, to possibly as high as 185 TWh by 2045 (with the equivalent of 10 new 1,650 MW European pressurized reactors (EPR) coming online). The latest study from Svenska kraftnät on the long-term market outlook[14] contained analysis of several future scenarios. The use case with the largest contribution of nuclear energy had 110 TWh or 14,6 GW, far below the stated goal just mentioned. There is a difference in the planning by the TSO and by the government about the future transmission grid expansion. The interviewees have underlined the importance of having clearly stated expansion plans for the transmission grids and the derisking of the investment plans for new nuclear power plants.

Enabling long-term operation

Extending the operating life of a reactor beyond the original design life is called long-term operation (LTO). Nuclear reactors have a typical design lifetime of 40 years. Between 1970 and 1985, Sweden connected 12 reactors at Barsebäck, Oskarshamn, and Ringhals to the grid. Today, all Swedish reactors have been granted long-term operations for up to 60 years. The closure of the existing fleet at the end of their 60-year license would decrease Sweden's electricity production with 52 TWh of low-carbon energy by 2045. Prolonging the lifespan of the six existing reactors beyond the current 60 year should therefore be assessed.

In the US, on the other hand, the Nuclear Regulatory Commission (NRC) approved the application of the Surry nuclear power plant to extend its operational license to 80 years and has also approved operational license extensions to the 60-year mark for 87 of the 92 commercially operating nuclear reactors across the country. In France, the French Nuclear Safety Authority (ASN) is investigating the possibility of extending the lifespan of 47 out of 56 reactors beyond 60 years, while carrying out the fourth decennial inspection of the country's 900 MW and 1,300 MW reactor fleets.

The OECD Nuclear Energy Agency (OECD-NEA) have presented that LTOs are the most cost-competitive solution at the plant level with construction cost of US$450 to US$950 per kW (On the 2023 November Capital Markets Day Vattenfall stated that the plant uprate and LTO for the three reactors at Forsmark and two at Ringhals would cost SEK50b) being far lower than anticipated nuclear newbuild construction costs of US$2,000 to US$7,000 per kW (e.g., an EPR with 1,650MWe could cost between US$3.3b to US$11.5b).

LTOs can be an effective market-based solution for nuclear financing, given a benefit from a strong production track record, clear asset view, lower transaction price and limited cost overruns and delays. LTOs have been financed successfully using a combination of export credits and commercial debt in several geographies, thanks to their higher bankable profile compared to newbuild.

LTOs are an important part of the future nuclear energy program in Sweden, as leveraging the existing infrastructure will support the economic value proposition. However, interviewees emphasized that LTOs help maintain the current generation level, but do not represent new capacity in support of projected demand growth in Sweden toward 2050.

14 Långsiktig marknadsanalys, Scenarier för kraftsystemets utveckling fram till 2050, Ärende nr: 2023/4164, Svenska kraftnät

Key takeaways on announced nuclear ambitions:

- The Swedish government has identified the need for nuclear energy development and presented targets for 2035 and 2045. The government is encouraged by several interviewees to explore and enable multiple pathways, including extended long-term operations, large reactors and small modular reactors.
- By 2045, the existing six reactors will have exceeded their 60-year operating license. Interviewees see long-term operations as the most cost-effective, but not sufficient option for continued nuclear power in Sweden, by leveraging the existing fleet and minimizing implementation risk.
- There is a risk of a bottleneck in the 2025–2040 period when several European countries will support the deployment of new reactors at the same time. This could lead nuclear technology vendors to prioritize which programs they are able to support. Consequently, the Swedish government might have to act quickly to clearly define its ambitions and the public resources it is prepared to mobilize in order to attract nuclear newbuild resources that are currently scarce.

3.2 Challenges to nuclear energy implementation

Interviewees broadly agreed that a rapid scaling of nuclear energy in Sweden would present significant challenges, based on the long lead times required at both the program and project levels. Many remarked, nonetheless, that it was accomplished 50 years ago when the oil shocks demonstrated the need for a strong baseload electricity generation to replace fossil fuels. The fact that Sweden put online 12 reactors in 15 years was seen by numerous interviewees as a testament that when political and industrial focus is achieved, lofty ambitions can be reached.

Sweden exhibits a decline in nuclear energy development experience. The country will need a heightened level of detailed planning and public policy involvement to meet the stated expansion goals. This requires tackling a multitude of challenges at the program and project level.

Interviewees pointed out that nuclear newbuild programs have not been undertaken in the OECD since the liberalization of electricity markets. Single reactor such as Olkiluoto unit 3 in Finland and Flamanville unit 3 in France, or pairs of reactors such as Vogtle units 3 and 4 in the US and HPC units 1 and 2 in the UK do not offer the nuclear supply chain or financiers the opportunity to scale. Furthermore, these projects were undertaken in isolation of each other and in the context of non-level playing fields featuring fully matured fossil-fuel-fired- and renewable technologies that benefited from special regimes such as free emissions certificates, priority dispatch, multilateral financing and investment or production tax breaks.

Interviewees pointed to critical program-level enablers that could make a difference to individual project economics, such as regulatory harmonization (whereby regulatory standards can be jointly developed, and approvals jointly processed, across multiple countries), a national framework for simplifying investment in critical infrastructure (by lifting obstacles in permitting, procurement, offtake, state aid, etc.) and government leadership in common infrastructure issues for nuclear owner-operators such as stakeholder engagement, education and financing. To illustrate the impact of the absence of program-level support, and the common challenges faced by newbuild investors in different markets, two case studies in the fields of large reactors and small modular reactors development have been reviewed. Flamanville 3 is an EPR first-of-a-kind (FOAK) that reflects a similar state to current day in Sweden, where a loss of development experience in the face of considerable project challenges led to a difficult path to completion. NuScale is the most advanced SMR developer in the OECD, and the recent failure of its carbon-free power project (CFPP) in the US is the most up-to-date example of how a FOAK SMR project can publicly fail and be abandoned despite significant (but incomplete) government support.

Large reactors case study: Flamanville 3

In the 1980s and 1990s, the French nuclear energy program built its last tranche of generation III reactors, with 4 N4 units (1,450 MW) installed at the Chooz and Civaux nuclear power plants between 1984 and 1999. This achievement of the French nuclear energy program rested on the high industrial readiness reached by Électricité de France (EDF) after the rapid scaling of nuclear energy in France between 1970 and 1980 (52 reactors built in two series of 900 MW and 1,300 MW designs) and the willingness to improve safety designs following the accidents at Three Mile Island (1979) and Chernobyl (1986).

A French-German collaboration between Siemens and EDF (formerly Framatome, and then Areva) led to the creation of the European pressurized reactor, a 1,650 MW reactor whose basic design was completed by 1997. However, political changes in France and Germany, with their elected governments, opposed to further nuclear development and slowed the approval and licensing, with the German regulator pulling out of the project completely. By the early 2000s, French authorities were unwilling to authorize the construction of a new series of reactors in France. They were dealing with several unresolved issues: the high cost of nuclear compared to gas-powered plants, a potential threshold effect by 2020 when reactors would reach their 40-year lifetime design limit and the need to maintain EDF's industrial capacity in case a new series of reactors needed to be built.

The formal decision to build the EPR at Flamanville was made in 2006, following a successful bid for the Finnish Olkiluoto 3 plant in 2003 where the Areva or Siemens consortium committed to deliver an EPR in 48 months (construction period) for about €3b[15]. At the time, EDF was concerned that the Finnish detailed design would be the only blueprint at its disposal and would require significant adaptations when transposed in a French context.

While this provided a critical path for EDF to demonstrate the feasibility of its new design, the complexity of the upcoming works and their associated costs were largely underestimated. Between 2005 and 2019, costs increased from €3.3b to €13.2b[16]. These costs overruns were attributed to e.g.:

- Scope changes for subcontractors, and a sharp increase in the number of engineering and study hours (from 5m to 22m) needed to finalise and update the design of the plant.
- Increased materials consumption as compared to original design due to poor works quality (most notably in the nuclear concrete).
- Regulatory changes during construction, most notably on the reactor vessel design.
- Work delays and their impact on the construction planning, components delivery and labor hours necessary.
- FOAK costs attributable to adaptations to the original design and issues linked to the initial studies, components fabrication and other worksite issues.

Initial estimates on both the cost of construction and duration of the works (54 months) were based on extrapolations from N4 reactors where the EPR would be built in a series of six reactors in two tranches on the same site. However, when looking back at the N4 series, its FOAK reactor at Chooz B1 took 142 months to build, while the last reactor of the same design at Civaux 2 took 98 months to complete. This construction planning, therefore, underplayed the complexity of the EPR design to future project stakeholders.

Additional design and engineering changes led to a €2.3b project markup (or a 70% increase on the cost of the initial design of €3.3b) caused by insufficient analysis of the impact of new safety features on constructability of the plant. Basic design of the plant was completed before the beginning of the project, however, additional detailed design and studies (fire safety, corrosion, materials, etc.) were lagging. By 2007, only 2m engineering hours had been put towards completing the design of the EPR, out of the 5m believed to be necessary to finalise this step. In the end, over 20m hours were needed.

These belated detailed design studies led to over 4,500 design modifications in the middle of the works, which cost time in re-adapting existing plans to new requirements and considerable expense in labor hours and supply chain adaptation.

Repeated regulatory changes by the ASN, including on flooding and seismic risk after the Fukushima accident, also impacted the delivery of the project. For instance, the reactor vessel of the EPR was first forged in 2006, but the first preliminary approval for its installation was given in 2018. This happened after several new safety assessments, which delayed the project.

The most recent N4 reactors to be built in France had their first nuclear concrete poured between 1984 (Chooz B1) and 1991 (Civaux 2), meaning that when construction began in 2007, France had a 16-year gap in industrial readiness and critical skill and knowledge transfers from one generation were limited. The nuclear supply chain had decreased in certain areas as public policy provided limited visibility for all players involved.

On the financing side, EDF was reported to require limited-recourse financial support from the capital markets to derisk their balance sheet and growing debt burden, while demonstrating to the European Commission (EC) and market that nuclear newbuild could be competitive with minimal additional measures from the state (i.e., state aid).

Under the Exeltium structure, which closed in 2008, limited recourse finance was raised from a group of banks, raising an estimated €1.75b for EDF on an upfront basis to complete the project. The bank market is understood to have helped EDF engineer a synthetic long-term capacity market. This was achieved by making a large upfront payment for 15-year capacity from EDF's nuclear fleet, successfully connecting EDF's energy-intensive end users with its nuclear fleet without contravening the highly restrictive state aid rules

15 Folz J.-M., (2019), La construction de l'EPR de Flamanville.
16 EDF press release (2022). Available here: Update on the Flamanville EPR | EDF FR

that disallow end users from entering into long-term, fixed-price contracts.

The ultimate offtaker group was an array of industrials for whom predictably priced, reliable energy was an important feature of their competitive business model. Unfortunately, the complexity of the transaction led to significant delays in reaching financial close, leading some in the banking industry to believe that financing newbuild nuclear without some measure of state support was essentially a non-starter.

Key takeaways on large reactors case study:

- Interviewees emphasised that individual projects cannot be competitive or economically successful in the absence of a supporting program-level framework so that issues of common nuclear infrastructure can be addressed at the national (or international) level.
- Regulatory support and visibility is important to limit increasing levels of design adaptations between reactors within the same program and also between countries. A high level of coordination with other European regulators is, therefore, beneficial.
- Many interviewees pointed to human resource mobilization and training as a critical factor in ensuring the success of the program. In a likely labor-constrained market, there is concern that European countries will have to compete for a limited pool of experienced contractors to complete their nuclear energy programs. Sweden was encouraged, therefore, to mobilise all of its industrial knowledge base to be able to support its deployment goals.
- Interviewees stated that industrial and supply chain development need to be carefully monitored and supported by long-term policies of the Swedish state. Strong support of the domestic value chain is believed to be a key component of the success of the program. The availability of foreign resources could also be constrained by other nuclear programs in Europe.

Small modular reactors case study: the carbon-free power project

Founded in 2007, NuScale is an American start-up that designs and markets water-cooled, multi-module SMR plants named VOYGR[17]. Its power plants can be configured with four, six or 12 power modules of 77 MWe each, providing between 308 MWe and 925 MWe on a single site.

In 2013, the US Department of Energy (DoE) announced up to US$226m to support the company's design certification. In 2020, NuScale received a standard design approval license from the USNRC for its 50 MWe module. It will seek approval for its 77 MWe modules by early 2025. Between those dates, the US DoE had provided about US$600m to support commercialization of SMR technologies to several companies, including NuScale[18].

In 2014, NuScale along with the Utah Associated Municipal Power Systems (UAMPS), announced that it would build the first American SMR at the Idaho National Laboratory, a site provided on publicly owned land by the US DoE. The UAMPS is a political subdivision of the state of Utah which provides energy services on a non-profit basis to 50 members from Utah, California, Idaho, Nevada, New Mexico and Wyoming, which are mostly municipalities. This collaboration was called the CFPP. It would be a landmark transaction for the industry, underpinned by strong US government support throughout the various stages of development (siting, licensing and funding).

Initial designs submitted to the NRC in January 2017 for a 12-module plant (VOYGR-12) indicated a plant capacity of 570 MWe to be built at under US$3b by 2030 (c. US$5,300 per kW)[19]. To help the project break ground, the US DoE approved a generous cost-sharing plan of US$1.355b, or around 45% of total project costs, to be paid in yearly instalments over 10 years[20].

By 2021, however, due to a significant increase in costs caused by inflationary pressures on the supply chain, the project had to be revised down from 12 modules to six, with a redesign using the 77 MWe module, for a total anticipated capacity of 462 MWe and a price tag of US$5.3b (approximately US$11,500 per kW)[21]. This downsizing also led to an updated target power price of US$58 per MWh and the inclusion of an option for UAMPS to withdraw from the project and be reimbursed for most out-of-pocket expenses if the price of energy per megawatt-hour exceeds a certain threshold. Over the ensuing years, the anticipated costs kept increasing, and some of the participating UAMPS members dropped out of the CFPP, thanks to the pre-agreed clause, further straining the project.

By January 2023, the CFPP approved a new finance plan where total costs had increased to around US$9.3bn (c. US$20,100 per kW), with a target price of US$89 per MWh after the application of a US$30 per MWh subsidy from the US DoE (using cost-share award of US$4.2b on the total project costs)[22].

After an off-ramp period, in which additional due diligence and scrutiny were given to the CFPP, 26 out of the remaining 27 participants of UAMPS decided to continue pursuing the project[23]. NuScale's CEO John Hopkins announced that the project could only continue if three conditions were met, including:

- Continued government support in funding the program
- The definition of an acceptable target price per MWh with no further cost increases beyond the US$89 per MWh mark (reflecting the low pricing threshold for the energy-only market in the western US market)
- Sufficient subscription by UAMPS members to the project capacity with at least 80% commitments by the end of 2023

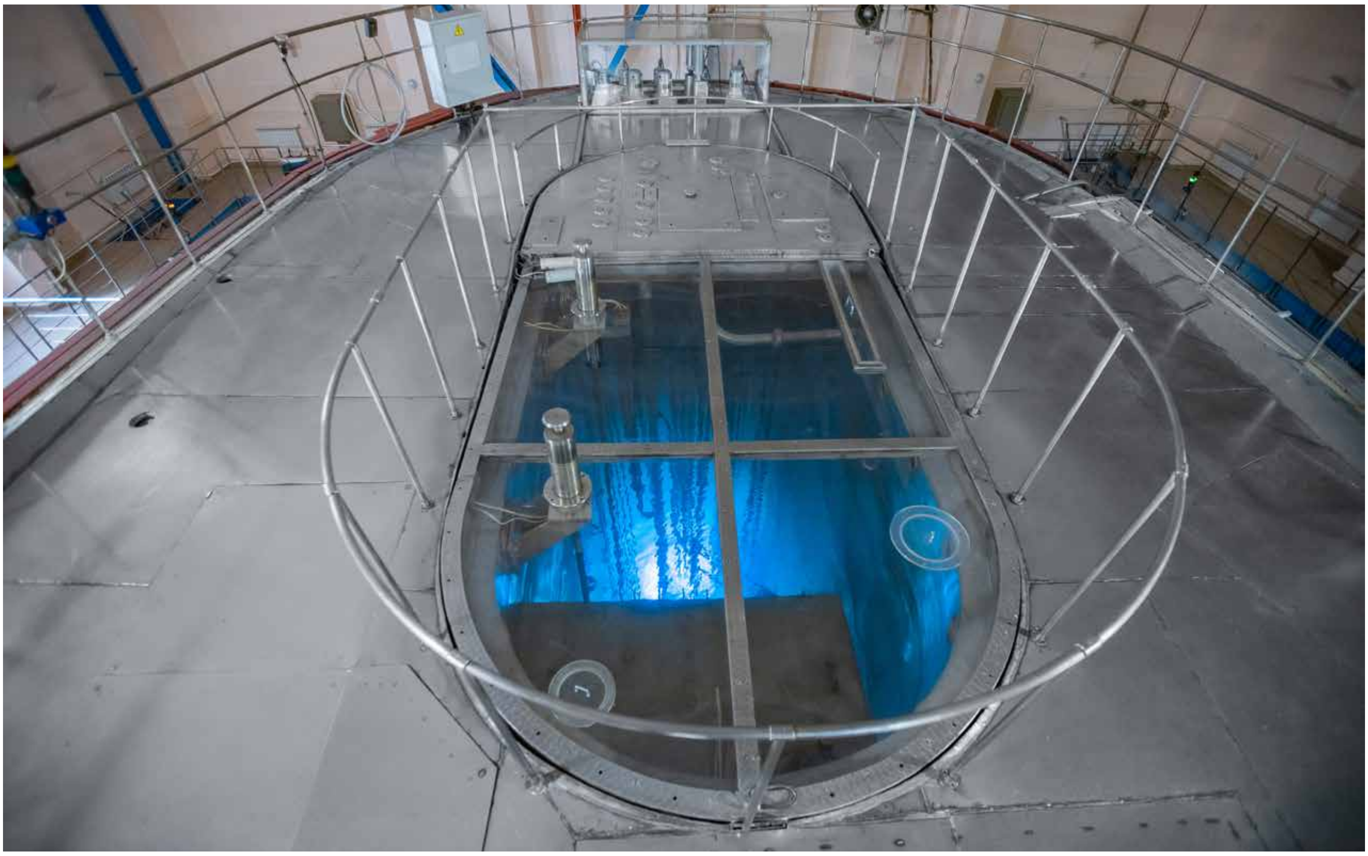
17 NuScale SMR Technology, 2021
18 NRECA press release (2023). NuScale Power Ends Small Modular Reactor (SMR) Project with Utah Wholesale Power Group
19 Usine Nouvelle (2020). NuScale franchit une étape décisive pour le développement d'un mini-réacteur nucléaire
20 UAMPS press release (2020). DOE cost-share award of $1.355 billion is approved for UAMPS' Carbon Free Power Project (dated October 16th, 2020)
21 Utility dive (2022). NuScale makes public debut but requires 'a lot of financing' to launch small nuclear reactor in 2029
22 Reuters (2023). NuScaler ends Utah project, in blow to US nuclear power ambitions
23 UAMPS press release (2023). CFPP Project Update dated March 1st 2023 (33rd edition)

While the first two conditions could be met, the third was proving more complex to fulfil. Indeed, the UAMPS members had to convince their offtakers to purchase the spare capacity of the plant and had issues achieving a lasting level of subscription. By 2021, only 103 MW had been subscribed, down from 150 MW in 2019, representing only 22.3% of the plant capacity and a low level of participation from offtakers. Thus, by November 2023, UAMPS and NuScale announced the cancellation of the project due to insufficient subscriptions[24].

Despite that, the CFPP had received US$232m in DoE support by the time it was cancelled and has proved to be a first testing ground for the implementation of an SMR in a western country[25]. NuScale was the first SMR company to receive a design license from the US NRC and has allowed for considerable development experience to be accumulated at the regulatory and development level.

The CFPP project, while innovative, was seen to proceed with an inexperienced counterpart in UAMPS, a company with no track record in nuclear energy development. Furthermore, despite their rate-regulated environment, CFPP offtakers had no capacity to bear financial risk on behalf of the project for its final customers. Furthermore, the electricity market in the region was noted to be very competitive due to the high availability of gas-powered plants at low prices, on top of abundant wind energy deployments, leading offtakers to under-value nuclear energy, despite CFPP's target of US$89 per MWh target, which could be considered competitive by international standards.

This challenging project structure and policy environment damaged the project by preventing a consistent level of subscription from UAMPS customers. While NuScale tried to downsize the project to better match the expected demand, this meant that fewer units bore a greater share of increased development costs and limited economies of scale.



24 NuScale ends Utah project, in blow to US nuclear power ambitions, Reuters, November 9 2023
25 UAMPS and NuScale Power Terminate SMR Nuclear Project (powermag.com)

Being a publicly listed firm since December 2020 with an initial offering price of circa US$10, the financial market reaction was unforgiving as NuScale share value dropped to around US$2. This was understood to be a reflection that NuScale was no longer seen as being able to credibly deliver against the original promises and targets made when the company was listed and sold in a public market with mixed maturity of investor experience. Wall Street analysts have indicated that NuScale's investors, who may have been originally motivated as short-term momentum and impact investors, were rotating out and being replaced by more solid, but also more cautious, investors with a longer horizon.

The US$89 per MWh target was widely seen as highly ambitious for a FOAK SMR, despite the VOYAGR design's high degree of engineering replication and business-led approach to the company's development work. However, interviewees queried as to whether NuScale sought additional, or alternative, types of support from the US government. Cost share represents a historically effective subsidy mechanism, but in this case, with the benefit of considerable hindsight, interviewees asked if there may have been a misread among the project proponents between investor support requirements (namely, DoE's cost share, a subsidy that is not recoverable) and offtaker support requirements (e.g., a tariff subsidy that is recoverable over the long-term life of the asset).

Key takeaways:

- In order for government (and the market) to reliably test the value proposition of the SMR sector, interviewees strongly encouraged incentives for the constituent entities of a nuclear program to work together and develop early collective bounding conditions for government consideration and potential support.
- Interviewees almost unanimously indicated that significant financial support in the early project stages is necessary to bring R&D SMR concepts to an advanced design stage. The Swedish government should investigate providing sufficient grants and cost-sharing programs to bridge the "valley of death" that nuclear energy startups face in implementation. Additional SMR projects supported by traditional vendors could also require support.
- The EY organization was informed that providing a comprehensive and enabling licensing process is necessary to speed up the deployment of SMRs and collaboration with other European regulators needs to be envisaged. Such an initiative is currently underway for the Nuward SMR between SSM and the Czech, Polish, Dutch, Finnish and French regulators and should be considered also in further applications.
- Some interlocutors pointed to offtaker confidence-building measures such as tariff caps or subsidised power purchase agreement (PPAs) to support a FOAK SMR project. They noted that offtake support alone but might not be enough to reach financial close.
- Market design measures were recommended to enable the full value of nuclear capacity and energy to be monetized by system end users. This was seen as necessary to assure full cost and benefit transparency to end users and level the competitive playing field across all technologies.
- Private developers backed by inexperienced and potentially impatient passive or financial shareholders were noted to have less financial resilience than large utilities and governments. Certain interviewees believed professional financial shareholders and lenders (whether venture capital, institutional pension funds or commercial banks) to be unreliable to deliver FOAK nuclear units in competitive markets unless there is a complete government-led support framework, touching on any combination of cost sharing, direct financing, offtake support and project development support.

3.3 Lessons learnt from precedent case studies

While complex infrastructure projects such as nuclear face a multitude of challenges at the onset, historical precedent demonstrates that Sweden has been able to overcome them with careful industrial planning, state involvement and a clear sense of political direction. On these various aspects, this report will cover a wide range of perspectives to identify the key areas that affect (1) program-level requirements to achieve the necessary industrial scale and (2) project-level management best practices between the pre-development stage and the FC or FID milestone.

Program level

At the program level, government support and policy guidance would be needed to sustain the necessary pace of development for nuclear energy. Most of all, first-in-a-while risk needs to be limited by ample support at all levels of the project lifecycle, from the design and research phase, to development, construction, operations, back-end- and end-of-life activities. In addition, governments in competitive markets have tended to underestimate the workload and timelines required to create an enabling hosting environment for nuclear FID, including updating legislation, regulations, permitting procedures and criteria, grid requirements, site selection, power market design and nuclear infrastructure such as facilities for long-term storage or disposal, including decommissioning.

The projects at Flamanville 3 and the CFPP faced competitiveness and bankability issues due to value-for-money justifications, which could not hold up when looking at plant-level economics despite obvious system-wide economic benefits. Across Europe, policy stop and go's for nuclear energy rested on the assessment that nuclear energy led to a structurally more expensive electricity system because of an expensive cost of generation, while forgetting the considerable grid stability and level of control that such a technology brought. Recent academic literature[26] has started to look beyond traditional economic competitiveness metrics at the unit level (such as the levelized cost of electricity (LCOE)). New technology-neutral metrics are being developed to inform what an optimal, controllable and low-carbon electricity system should look like by 2050 including capacity-equivalence, total emissions (including Scopes 2 and 3) and total life cycle costs.

Nonetheless, the shortfall of nuclear development experience across Europe is an obstacle to the rapid scaling of the program. Market actors have not recently committed meaningfully to nuclear as an asset class for lack of investment signals. The state can benefit from bringing a holistic but targeted derisking strategy to the table. That means offering incentives and taking on risks at the beginning of the program, to ensure that an adequate level of self-sustaining industrial and financial experience is accumulated and paid back in the market of consumers, shareholders and, ultimately, taxpayers. Such a strategy is not unique to nuclear. Financial support has been provided to renewable energy projects in the past twenty years. As early as 2009, total levels of support were greatest in Germany where over €10bn per year[27] was provided, mainly in the form of feed-in tariffs. Batteries and hydrogen factories also benefit from subsidy schemes as their industrial importance has been well demonstrated to the future of the energy transition.

Industrial development policies can enable an increasing share of the supply chain to be in Sweden on a cost-efficient basis. This could include a comprehensive labor plan to provide trained workers at the construction site, appropriately qualified components manufacturers and certified subcontractors (welders, boilermakers, engineers, designers, etc.), including a coherent sourcing and identification phase. Committed order books with long-term commitments and detailed working plans would lead to industrialisation opportunities in fuel supply, components manufacturing and nuclear-certified workforce mobilization.

26 OECD-NEA and IEA (2020). Projected Costs of Generating Electricity — 2020 Edition
27 Ecofys (2011). Financing Renewable Energy in the European Energy Market

Perhaps equally importantly, Swedish industrialisation could benefit from the prospect of low-cost nuclear energy that would be sold at predictable costs over long timeframes. Nuclear energy was mentioned as a historical competitive advantage for industry in Sweden as well as France and the US.

Project level

As was indicated by the nuclear vendors, owner and operators in the interviews, at the project level, best practices include a detailed development plan that defines the business plan across the lifecycle, from early development to shutdown and post-shut-down activities.

First, a careful derisking plan for all stakeholders be detailed to reach FID on economically sustainable terms. This includes defining a clear development model and identifying the key roles of each counterparty in the process.

With the current lack of nuclear project experience, the trajectory to reaching FID is unclear in terms of cost and schedule. By tackling the sequence of project hurdles, the state can provide a template development model that will be the basis of future private-led investments. The main goal of this phase is to reach bankability and an optimized value for money assessment, thanks to overall government-backed derisking.

Second, once the development phase has been addressed, a clear operational and financing model can be deployed. This will include predictable and long-term revenue support, a clear allocation of risks between defined plant owners, plant operators and private finance, a standardised plant delivery and construction model and additional government support to plug the remaining gaps to investability as determined by outside investors and lenders.

The combination of such a development and investment model will form the basis of a conclusive Swedish nuclear investment model for the future. This should take Sweden from a government-backed process (financially speaking) for the first few units to an industrial and private market growth model for the rest of the program. Such a model has been successfully demonstrated for nuclear 40 years ago and for renewables today.

Key takeaways on lessons learnt from precedent case studies:

- The interviewees with experience in nuclear development indicated that target investment model parameters must be identified, and ranges or bounding conditions and trajectories agreed by the primary commercial or financial or industrial and governmental stakeholders.
- The major nuclear actors in the interviews shared the view that a clear development model must be identified, agreed and launched under government oversight, incentivizing and driving market players to contribute to nuclear energy deployment on an economic basis, enabling any or all participants to add value to the future nuclear energy investment proposition, or alternatively drop out via off-ramps without significant financially damaging consequences.

4 Considerations for Sweden's long-term nuclear program

The Swedish government's nuclear newbuild target[28] can be supported with economic justification and risk management to be deliverable and sustainable. This applies to any new policy, including the nuclear industry that is highly sensitive to policy stability because of the lead times and amount of capital investment required both at the program and project levels. The nuclear investment ecosystem of the 1970s and the 1980s has been replaced by policies and market designs that require a complete accounting of the full costs of nuclear but not necessarily the full benefits. With the new government appointed investigator for the electricity market (see section 3), the market design are to be reviewed to better suit a doubling of electricity demand, including contributions from new nuclear power.

4.1 Pre-conditions to an effective nuclear energy deployment

In section 3, this report captured preconditions to enable a successful program implementation identified in the interviews such as:

- A sustained, and broad-based political support for the program going beyond traditional electoral cycles.
- A comprehensive value-for-money assessment, which brings out the full value of nuclear for an electricity system.
- An expanded, modular approach to funding and financial support throughout the program lifespan.
- A comprehensive industrial and supply chain mobilization to back the anticipated expansion.

A value-for-money assessment, which includes the comparison with intermittent generation sources and compensation, is believed to help clarify where government resources are to be allocated, and accordingly where the mobilization of capital resources by the private sector can be achieved for nuclear and nuclear-adjacent investments. From the interviews performed, there was a clear consensus on the need to have a broad political agreement among parties to minimize the risk of halting or complete stopping nuclear projects, even at front-end engineering and design (FEED) phase. The risk of short-term political actions affecting a new nuclear program will inevitably drive an increased financial risk premium not only on capital provided but across the whole supply chain. Government support was said to be credible for the market, and therefore sustainable, if it is "enough but no more." Discussions with stakeholders revolved around government support concepts that feature nuclear design neutrality, modularity and incentives. A smaller number of interviewees indicated government support for nuclear could, in fact, be entirely technology-neutral though they also recognized the specificities of nuclear energy with respect to safety, security, safeguards, project and program complexity, public acceptance and overall timelines that make head-to-head evaluations across technologies very challenging for any government.

This section will explore how the Swedish government and the various program stakeholders can address the preconditions for broad-based market support.

Broad political consensus needed to mitigate political risk

The first nuclear era in Sweden (see section 2.1) was underpinned by a consistent political will which provided long-term visibility to allow sufficient planning across the supply chain. A program view over a long period is a key driver of cost reductions because it allows for a complete design, licensing and industrial optimisation and maturation process to take place. Significant development and design costs can be recouped, not at a single-unit level, but through a significant series effect spread over a larger number of similar units.

28 Färdplan för ny kärnkraft I Sverige, Swedish Government, November 2023.

In 2008, the UK issued a nuclear newbuild policy white paper,[29] recognizing the technology's dependence on certain public resources (regulatory safety, land and water use, safeguards and security, public education, nuclear liability and potential government financing, etc.). To secure public support, avoid disruptive legal challenges and calibrate the future allocation of public resources, the UK government undertook a multistep process involving public consultations, safety justifications, strategic siting decisions, market designs and access to financial support. Shortly after the issuance of the UK's white paper, a national policy statement was released, but the policy support instruments (the regulated asset base (RAB) legislation and enabling instruments) were not identified or addressed until 2019 (RAB consultation) and 2022 (RAB legislation). His Majesty's Government (HMG) currently maintains its FID target before the end of the year, five years after the initial RAB consultation and 16 years since the white paper.

Based on the UK experience, which is similar to Sweden in the requirement for market support of the program, it is advisable for the Swedish government to establish an investor-level roadmap. This would help set mutually agreeable targets, efficiently orchestrate the allocation of public versus private resources, manage expectations and generally raise confidence levels.

At the political economy and industrial policy level, the example of the prior French approach might have been instructive for UK decision makers and may still be so for Swedish policy and decision-makers. France's early nuclear program was managed through a government-led plan that aimed to achieve a complete energy and technical independence, while meeting the growing energy needs of the country. With an initial target of 13 reactors to be completed, a strong industrial leadership borne by the state-owned utility (EDF), the industrial sector was able to reach an adequate level of readiness over a 10-year period to deliver significant capacity. French build-out was inscribed in broad economic policy terms, rather than pure energy policy. The demand-pull effect of the EDF nuclear program led to the conversions of several industrial players which previously worked with coal mining, aluminium and steel production. A significant effort to standardize the fleet could also be carried out, as the increasing pace of installation (with up to eight units commissioned in 1981) allowed EDF to set industry standards for the whole program. The French government targeted to install around 100 GWe by the year 2000, but that was revised down to 63 GWe to avoid overcapacity as the actual electricity demand from the country did not grow as fast as expected.

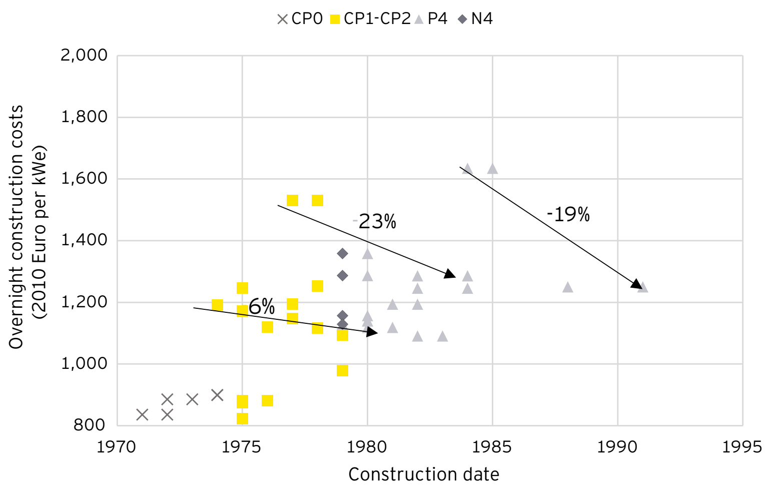


Figure 4.1: French historical nuclear program with series effect reflecting in overnight construction costs

29 MEETING THE ENERGY CHALLENGE A White Paper on Nuclear Power CM 7296 (publishing.service.gov.uk)

Looking back at the development cost of nuclear, as highlighted by France's National Auditor Office (Cour des Comptes) in 2012[30], the overnight construction costs of the French fleet achieved significant reductions over the years, see also figure 4.1. Benefiting from significant series effect with a falling average construction cost for a reactor of the same design, France leveraged two powerful optimisation enablers:

- A program effect originated by decisions of the architect-engineer (vendor managing the project and the reactor construction) whereby costs are reduced, thanks to uniformity of studies, developments, qualifications and testing.
- A productivity effect seen mostly in the supply chain, with suppliers passing on gains in productivity in their prices. That is dependent on the visibility given to suppliers with a guaranteed order for series of identical components.

By the early 2000s, as highlighted in the Flamanville 3 case study in section 3.2, most of those development and industrial capabilities had shrunk due to a slowdown in nuclear newbuild between 1991 (Civaux 2) and 2006 (Flamanville 3). Further lack of visibility on the EPR development program limited the supply chain readiness as the French government hesitated to cancel any new nuclear energy development. Inconsistency in long-term nuclear perspectives led to well-publicised issues that impacted the new EDF design, as it prevented the achievement of a series effect.

Another nuclear power program is that of South Korea, where the government has provided consistent development targets to the nuclear energy sector, see figure 4.2. At the time of its inception in 1968, no homegrown sector existed, and the state insisted on benefiting from technology transfers of foreign designs and indigenize key nuclear capabilities across the value chain including design, manufacturing, construction and operations and maintenance.

Affected by the oil shocks in a similar way the western countries were, Korea's long-term ambition to establish a nuclear technological capability led to the creation of a technical self-reliance plan in 1984, which aimed at localising 95% of Gen II-type designs by 1995.

The creation and development of the Gen III APR-1400 beginning in 1992[31] was pivotal in making South Korea a player in the nuclear energy market, and the design has been used in three large projects (Shin-Hanul and Shin Kori in South Korea, and Barakah in the United Arab Emirates (UAE)) with eight operational reactors, and another four under construction as of today.

Figure 4.2: Overview of South Korean domestic and export nuclear program

30 The costs of the nuclear power sector, Cour de Comptes, 2012
31 Status report 83 – Advanced Power Reactor 1400 MWe (APR1400), IAEA 2011

The scale achieved by this Gen III program has enabled the South Korean nuclear industry to look internationally for its development when it was previously focused on safeguarding the country's energy supply.

In 2008, a consortium, led by Korea Electric Power Corporation (KEPCO) was chosen as contractor for the delivery of the first nuclear power plant in the UAE's Barakah site[32] . This four-unit project avoided large schedule delays and limited cost overruns, with around a nine-year construction period for each of the reactors. Research from the Energy Technologies Institute (ETI) database[33] estimated that the capital cost of the Barakah nuclear power plant was significantly reduced between the first unit (US$5,452 per kW) and the last unit (US$2,300 per kW), a 58% drop. This reduction, citing strong learning effects particularly in construction, labor availability and experience, is shown in Figure 4.3.

32 KEPCO wins UAE civil nuclear bid, Nuclear engineering international, January 4 2010
33 The ETI Nuclear Cost Drivers Project, Energy technologies Institute, September 2020

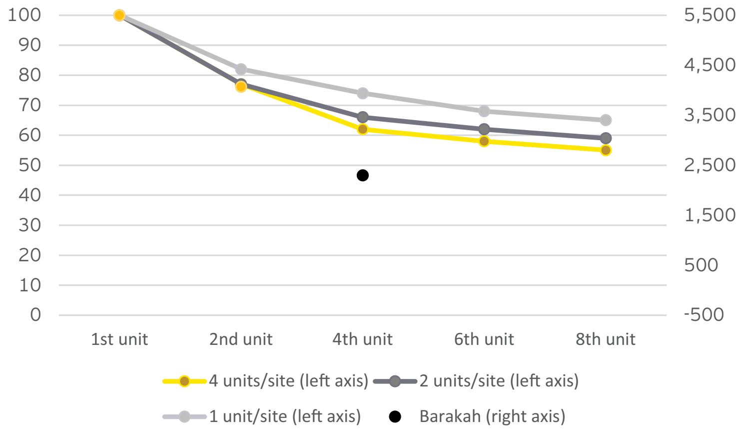


Figure 4.3: Barakah nuclear power plant overnight construction costs per unit based on NEA[34] and Goran[35]

Multiunit construction reduces non-recurrent development costs, e.g., site preparation, and infrastructure to the plant, and allows for a more efficient allocation of resources between units. Delays are better managed through e.g., team reallocations, common spare parts management and the rapid use of past learnings for the subsequent reactors.

A long-term program led by the Swedish government can benefit from using the lessons learnt in recent projects to unlock the best possible outcome. To transition rapidly from the first reactor to a Nth-of-a-Kind (NOAK) reactor with an experienced supply chain, the government will have to step in by providing visibility on its support policy and package, including criteria, for successive projects. To attract developers and induce investment, enabling policy measures would be expected both transversally (site eligibility, transmission system access, regulatory capacity, legislative and permitting mechanisms, etc.) and vertically (project-specific policy instruments, such as the tailored funding and revenue support that would be available to a given project).

As was made clear in the interviews conducted, political risk and policy stability were identified as the key roadblocks to a successful nuclear program. The management of such a long-term program should be depoliticized and several interviewees raised the idea that the work could be led by a dedicated, operationally autonomous agency that would coordinate the feasibility studies, the procurement of nuclear technology, and the development of the program. Such an agency would be tasked with operating as a one-stop shop, providing nuclear energy developers with the necessary support and guidance to fast-track permitting, funding and other key areas essential for launching their projects. This specialized agency could be created within an existing authority whose responsibility would be to bring the program forward. This agency would ensure the continuity of the program and allow a sustained policy effort to be converted in enough nuclear-generated electrons to support Sweden's continued economic growth. When developing the future solution including any agency structure the competition law would need to be taken into consideration.

The goals of the Swedish program, alongside plentiful energy supply, technological independence and decarbonization, could also be to promote the best possible program economics. Heavy industry, which plays a critical role in Sweden's future economic potential, is largely reliant on a secure and competitive baseload power source to reach its full potential. Reaching a competitive price of electricity could therefore be a key objective in a nuclear program.

34 Reduction of Capital Costs of Nuclear Power Plants, NEA, 2000
35 The Potential for nuclear cost reduction, Goran 2019

Key takeaways on broad political consensus needed to mitigate political risk:

- Program-level success, matching the scale of Sweden's announced policy targets, requires a holistic, fleet-based approach for the nuclear industry, unseen in Sweden or the EU since the 1980s. Policymakers should establish a long-term program and industry strategy that offers visibility to market players, including investors and have clear view on the responsibility for organizing and orchestrating the programme
- Policymakers should develop instruments and incentives for the industry to mobilise and absorb the upcoming workload generated by newbuild and operation of the nuclear reactor fleet.
- Government resources may need to be extensive at the outset and should be justified on a value-for-money basis. This can reasonably be achieved if support is modular, incentivized and considers the full nuclear life cycle benefits.
- At the program level, assess the costs, risks and benefits of a nuclear program so that that the associated costs and risks can be shared appropriately.
- Sweden can benefit from leveraging the lessons learned in previous nuclear power programs, including sustained industrial mobilization, long-term deployment planning and design predictability and maturity. In turn, the government can benefit from increasing interactions with other nuclear countries, particularly the ones undertaking newbuilds across Europe, to share capabilities, knowledge and best practices.
- While nuclear energy will likely require support during its start-up phase by government financial contributions, limited fiscal headroom and the natural tension between policy priorities will direct the long-term financing of the program to market players. To achieve a bankable investment proposition, the government will need to enable a credible business case to market players by targeting key execution risks.
- An investor-focused roadmap would be advisable to raise confidence levels in the Swedish nuclear newbuild program among market participants.

Importance of bank ability, invest ability and economic competitiveness

Nuclear power plants possess similarities with other large infrastructure projects, both within the power generation sector and in other industries. However, nuclear energy itself has several special characteristics which can make investments in newbuild different in several areas from other large projects, making financing more difficult:

- Complex licensing and regulatory assessment phases.
- The capital cost and technical complexity of nuclear power plants make the construction period particularly prone to delays and cost overruns (mostly in the case of FOAK and first-in-a-while projects) and increase risks during operations (equipment failures and unplanned outages).
- A long, compared to other energy assets, investment and capital mobilization period lead to difficulties in recouping investment costs and in raising and repaying debt.
- Nuclear power plants are well suited for baseload operations, the high-capacity factor driving capital recovery at generally lower required return rates than in load-following mode.
- Financing schemes and appropriate radioactive waste management and decommissioning plans need to be formulated in collaboration with the government.
- Nuclear projects can expose investors to face significant political and regulatory risks, due to the technology's links to national security and public safety. The most sustainable investment framework could reasonably shift most risks (and rewards) to the market, other than specific exclusions (such as the aforementioned specific political and regulatory risks) which the market should be requested to indicate or alternatively, if the risks are not considered "deal-breakers", to price into their models.

Nuclear energy investments have been facilitated in numerous ways in the EU and OECD, whether by commercial or financial partners.

Previous experience in the OECD countries shows that new nuclear power plant costs and risks have not been financed or underwritten exclusively by the market. This is partly because the market has found that not all the benefits of nuclear energy accrue to the project participants, instead they are widely dispersed and non-monetized across the economy and population. Equally, the complexity and investment volume of a nuclear newbuild program are considered to require active participation of the government, whether for power market pricing and design decisions, legislative and supranational rulemaking, extreme risk scenarios and potential short-term funding gaps.

To provide a framework for government involvement, several countries have made government support packages (GSPs) available for nuclear newbuild in recent decades. These GSPs have been structured in different ways, reflecting specific strategies and objectives of each country in developing their nuclear energy projects as well as budgetary and market constraints. Each GSP reflects particular nuclear maturity, industrial base and the electricity system options for the specific country. The main goal of government support is to both strategically and cost effectively reduce the risk perception of a nuclear energy project. Moving forward the content of a Swedish GSP should reflect both the political will and the nuclear value chain's ability to bear the cost of development and operation.

Today, the track record of construction issues, overruns and delays, of first-in-a-while projects leads to heightened risk perceptions from investors, driving a higher cost of financing called the "nuclear premium" together with restricted availability and liquidity. Financing conditions directly affect the cost of generation and the competitiveness of a plant. These conditions are influenced by the nature of the risks (higher risks lead to higher expected returns and cost of capital) and the organisational and ownership structures that allocate risks among stakeholders (essentially on financiers, vendors, and owners, rather than consumers and the state).

At a holistic level, however, it is important not to consider financing conditions per se as a lever to reduce the cost

of nuclear energy, as they simply reflect the underlying industrial organization, and government choices in designating the appropriate risk allocation and mitigation strategy.

Financing is, therefore, the output of overall project derisking, and government policy can significantly reduce risk perception and management of a nuclear asset, leading to better overall project economics. Thus, public policy interventions may be warranted to effectively assess, allocate, and mitigate those risks and decrease the overall cost of capital.

To understand the best way to decrease the risk perception of a nuclear project, OECD-NEA analyzed the cost of nuclear newbuild and identified three main components:

- Overnight construction costs, or the cost of engineering, procurement and construction contract, including the owner's costs of development
- Project structure and efficiency of management, achieved through a series effect and a project learning curve
- The cost of capital that affects the financing of the project including interests accrued during construction

Nuclear capital asset pricing model

The following explanation presents the well-rehearsed academic and public consensus on how the cost of capital impacts nuclear energy projects, and how to optimize it.

To identify the tools needed to optimize project financing, governments can refer to academic literature to assess the best way to derisk a low-carbon generation asset. Using financial economic theory, referred to as the capital asset pricing model (CAPM), a risk-pricing model is used to value all economic assets based on their expected risk and return profiles. The principle of CAPM is that investors will seek a return on their equity investment based on the risk-free rate, and the relative risk level of the investment itself compared to other equity investments. Thus, the cost of capital of a nuclear power plant project can be expressed as follows:

$$r_n = r_f + \beta_n * r_s + \sum_{i}^{n} r_{IN_i}$$

r_n: the cost of capital of a nuclear power plant project, i.e., the discount rate

r_f: the risk-free rate (equal to high-quality government bonds)

β_n: the correlation of the risk of a nuclear power plant project with systemic risk, i.e., market risk

r_s: the systemic risk, i.e., market risk premium

$\sum_{i}^{n} r_{IN_i}$: the sum of project-specific or "idiosyncratic" risk of a new nuclear power plant project, typically policy risk, electricity price risk, and construction risk

Cost of capital for a nuclear newbuild project in Sweden

As of March 2024, the yield on 20-year Swedish government bonds was close to 2.4% (), while its market risk premium was estimated at around 4.6%[36] ().

Correlation coefficients are hard to compute for standalone nuclear energy projects, rather than for entire companies with diversified portfolios of assets. Nonetheless, recent literature on Russian nuclear projects estimated a range of 1.56–1.93 for the nuclear power plants built in Kudankulam (India), Bushehr (Iran), and Tianwan (China)[37]. However, those reflect much higher risk factors due to the local context and the singular nature of those undertakings and are unlikely to be reflective of a program backed by a large utility or a government in an EU country, where risk premia are much more subdued.

Damodaran estimated that the β for renewable energy companies in 2024 was closer to 1.11, while utilities average 0.58[38]. Additional data comes from state aid cases published by the EC, where β assumptions of the financial models are provided for nuclear newbuild projects, such as PAKS II in

36 pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html
37 The Format of the IJOPCM, first submission (researchgate.net)
38 Betas (nyu.edu)

Hungary (1.01-1.08 in 2017)[39] and Dukovany 5 in the Czech Republic (0.40–0.55 in 2022).[40]

Additional literature suggests that "high-emitting assets are significantly more sensitive to economy-wide fluctuations than low-emitting ones,"[41] leading to a reduced β for low-carbon projects such as nuclear energy. As climate change and efforts to battle it intensify, carbon prices are likely to rise, decreasing the value of high-carbon investments, and increasing the relative value of nuclear power.

Ceteris paribus and assuming the above holds true, the beta (β) for nuclear energy could approach zero. This means that investors would be willing to accept lower returns for low-carbon investments.

While it is complex to independently quantify the nuclear risk premium, several sources have provided estimates. According to a Moody's study from 2013,[42] the announcement of a nuclear power plant construction project by American electricity generation companies degraded their rating by four notches on average. In Sweden, that would represent a downgrade from AAA to A+, or an additional premium of 0.7% according to Damodaran's database[43]. At Dukovany 5, CEZ, the plant owner, estimated a nuclear premium of 2.75-3.75% for the project, while the EC estimated that 2% would be appropriate for the PAKS II project.

Following those estimates, the band of discount rate for nuclear energy projects reaches 5.0%-15.0%. The level of discount rate also reflects the nature of the GSP provided to a particular project. Greater government support should drive the discount rate to lower levels.

Calculations provided by the IAEA (see figure 4.4 below), have demonstrated how sensitive nuclear energy is to changes in the discount rate. Using the above estimates, at a 5% discount rate, a standard newbuild project could produce electricity at around €59 per MWh, vs €153 per MWh at a 15% discount rate.

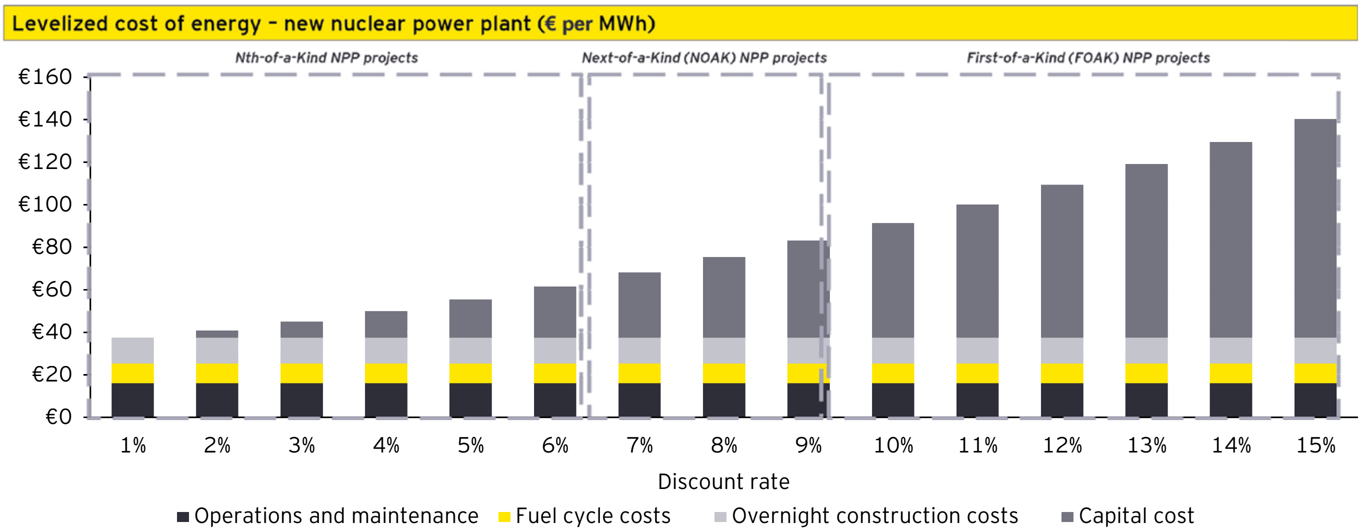


Figure 4.4: LCOE for new nuclear power plants

39 Decision – 2017/2112 – EN – EUR-Lex (europa.eu)
40 EUR-Lex – 52022XC0805(04) – EN – EUR-Lex (europa.eu)
41 Trinks et al., Energy Journal, 2022
42 Nuclear Generation's effect on Credit Quality (oecd-nea.org)
43 pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ratings.htm

With the objective to provide 100% fossil-free electricity production to 2040[44], the government can consider a comprehensive derisking support package to the nuclear newbuild developments and thereby bring down the cost of capital to competitive levels.

To promote nuclear energy development, novel approaches to financing and support policies are being pursued, including public investment, in equity and debt, and sovereign guarantees. Most nuclear power plants operating today were financed and constructed in regulated utility markets, therefore, having guaranteed offtake and high enough electricity prices to ensure a profitable rate of return. Under these conditions, cost overruns and project delays were covered by higher electricity prices. In addition, much of the financing for these plants was provided by governments or with government backing or government guarantees.

The financing of nuclear power projects has become more challenging since the 1990s. Utility markets, often monopolistic, have been deregulated and energy transmission, distribution and generation unbundled to encourage competition among electricity generators. As a result, nuclear operators have been increasingly exposed to price and demand risk, which increases the overall risk profile of new projects and the difficulty of obtaining private financing.

As previously highlighted, governments can provide visibility and certainty to program stakeholders to achieve the best possible level of industrial mobilization and standardisation over the years. Additionally, government support at program onset will prove critical in providing wide ranging tools to financially derisk the project, and thus lower the cost of capital for the project.

Key takeaways on importance of bankability, investability and economic competitiveness:

- A fleet-scale nuclear program was not seen as being financially or politically sustainable without a strong value-for-money proposition, including a credible path to market financing.
- Nuclear power, mostly FOAK and first-in-a-while plants, is believed to be less attractive to external finance, as their risk structure is not well understood by financial markets, and the recent history of project cost overruns and delays has heightened risk perception.
- Today, limited series and program effects combined with limited project experience over the last 40 years risks to drive construction risks and costs. This leads to a higher risk premium and therefore a higher cost of capital. Thus:
  - The interviewees highlighted that it is important to enable a reduction in overnight construction cost to competitive levels. Thus, encouraging the Swedish government to support a long-term nuclear energy program and series development.
  - The Government is seen, by several interviewees, as the primary player to reduce the cost of capital for nuclear construction by derisking the projects with targeted support measures that can be justified to taxpayers.
- Interviewees considered that targeted support could need to be wide ranging, including direct financing for early program activities and projects and a risk allocation model to help drive down the financial penalty of innovation in the market.

The Swedish government's role in nuclear energy funding

Historically, during the nuclear energy boom of the 1970s and 1980s, financial players, state-owned utilities and governments worked together to support the rapid growth of the industry by providing ample capital, technology development and sustained political support[45]. For instance, much of the debt that supported the rapid newbuild program in France was financed by market bond issuances in France and the US, with guarantees provided by the French state. While electricity markets were regulated and part of a natural monopoly, the increased investment costs of any single projects were recouped at a national level and limited project completion risk.

Today, with deregulated electricity markets, the nuclear energy industry has tried to find new ways to raise commercial financing. This has taken the form of traditional project financing, which proves both more expensive and

44 Färdplan för ny kärnkraft, Swedish Government, Novemeber 2023
45 The financing of nuclear power plants, OECD.NEA, 2009

time-consuming, while having challenges to manage the risks associated with nuclear power plants construction and operation.

Corporate finance was also another venue for financing arrangements, most notably for utilities, in France, UK, and US. However, these activities where mainly debt based and could have an overall negative impact on the capital structure of those companies. These activities are not adapted to power and infrastructure financing.

To some extent, some construction and completion risks can be shared with technology vendors, but recent company bankruptcies e.g. Areva reconstruction plan in 2016,[46] Westinghouse in 2017,[47] EDF was nationalized in 2022[48], have showed that these types of vendors only have limited capacity and willingness going forward, to accept such risks. This has caused a lack of cost-effective and scalable financing options for nuclear energy projects in Europe, which either rely on strong government financial support, such as seen in the Czech Republic for Dukovany and Temelin and Hungary for PAKS II, or more expansive balance-sheet based utility debt issuances such as in Hinkley Point C, Olkiluoto 3 and Flamanville 3.

Thus, as of today, there currently exists a financing gap that governments can address by providing the first backstop to new nuclear development. This support can be multifaceted. The gap can be expressed as five main axes through which governments can support projects:

- Direct equity contributions, either to the project owner or special project vehicle (SPV)
- Lender support through guarantees or sovereign issuances
- Revenue support to provide long-term cash flows visibility such as CfD, RAB, PPA, etc.
- Project risk allocation, e.g., state backing on overruns costs and delays
- Indemnification clauses and Investor insurance, including protection against changes in policy or early plant shutdown

The combination of all these axes can be referred to as a GSP, which aims to price in the risks and the positive externalities of anticipated FOAK, first-in-a-while and NOAK, next-of-a-kind, nuclear power plant projects. Sovereign states can justify the use of state aid on social and economic grounds by demonstrating the proportionality of the aid used and its necessity. Considerations for the positive externalities, in addition to the pure economic rationale of creating a strong baseload power source and a localised supply chain, should support the business case for a comprehensive GSP.

So far, the Swedish government has identified the need for lender support, through SEK400b credit guarantees announced recently[49]. Nonetheless, that assumes the Swedish nuclear energy program will be able to raise a considerable portion of its undertaking using market sources at a first-in-a-while and / or FOAK stage. However, this was considered, as part of the interviews, an insufficient analysis of the risks borne at this stage by potential vendors and owners and will likely delay the beginning of the program.

46 Areva outlines restructuring plan, press release, World Nuclear News, June 15 2016
47 Westinghouse Files for Bankruptcy, in Blow to Nuclear Power, New York Times, March 29 2017
48 France starts process to fully nationalise power group EDF, Reuters, October 4 2022
49 Uppdrag att vidta förberedande åtgärder för att kunna ställa ut statliga kreditgarantier för investeringar i ny kärnkraft, Swedish Government, Diarienummer: KN2023/04316

Table 4.1 captures the risks that were most identified by interviewees, with commentary on how government support could be measured and applied:

	Identified risks	Potential remedy	Example of application
Equity contributions or owner financial support	• High cost of capital • Low project bankability (at FOAK stage) • Political risk (potential of reaching FID)	Equity contribution from the government or that a government-related entity will ensure strong project buy-in, and tangible involvement.	At Dukovany 5, the Czech Republic plans to provide up to 90% of the equity commitment to the project, with the remainder borne by the utility CEZ (also 70% government-owned). At PAKS II, Hungary has accepted a 100% SPV exposure through the state-owned nuclear utility Magyar Villamos Művek (MVM).
Lender support	• High cost of capital • Low project bankability (at FOAK stage)	Government underwriting of the debt (either through direct loans, or sovereign debt issuances, or full guarantees), at preferential rates.	At Dukovany 5, the Czech Republic plans to provide sovereign debt for the entirety of the outstanding project costs. At PAKS II, Hungary benefits from an inter-governmental agreement (IGA) with Russia, which will provide a complete financial undertaking using sovereign debt.
Revenue support	Market risk (i.e., uncertainty surrounding long-run revenue estimates)	Long-term, predictable revenue support.	At HPC, UK has offered a 35-year CfD with a target price of £92.5 per MWh (in 2012 money). At Sizewell C, UK plans to provide a regulated asset base structure, which should cover all project costs plus a target fee to compensate capital providers. At Dukovany 5, the Czech Republic plans to provide a long-term PPA which removes volume and price risk from the plant owner.
Project risk allocation	• Unpredictable licensing, regulatory, and legal framework • Unknown funder of last resort (i.e. exposure to overruns costs and delays)	Clear allocation of risks between the state, the owner and the nuclear vendor when it comes to the supporting framework. Distribution of liabilities in case of overruns and delays.	At Sizewell C, UK intends to provide an extensive protection to plant owners in case of overruns with a RAB model and a clear framework for overruns funding with multiple tranches of exposure.
Investor insurance	Political risk (i.e., uncertainty regarding the long-term government position on nuclear)	Insulating project completion risk from political interference.	At Hinkley Point C, UK provided a compensation clause which could protect EDF from future Government's policy changes such as early plant shutdowns or program cancellations.

Table 4.1: Most commonly identified risks for each of the pillars of the GSP, with examples of countermeasures implemented in European countries in recent projects

According to several interviewees, the sufficiency and/or adequacy of SEK400b credit support can only be assessed in the context of the broader nuclear business model. Using risk definitions in table 4.1, the following conditions are examples of areas that would need to be further assessed:

- Clear owner to be identified in order to avoid a situation with a non-determined and non-determinable equity capacity requirement:
  - The financing capacities of the existing owners and operators and vendors and developers to be quantified and assessed against their current balance sheet and market conditions.
  - Assessment of how potential private capital can be leveraged, keeping in mind that it could result in a high cost of capital.
  - Potential government ownership (or at least direct equity contributions) would benefit from being assessed and quantified, keeping in mind that this can be included in some form to allow project completion.
- Debt financing strategy to be assessed, developed and implemented:
  - With an owner and a clearly defined target capital structure, uncertainties can be addressed as the eventual cost of capital would be estimated.
  - The nature of the credit guarantees, their beneficiaries and the project or lender selection criteria would need to be assessed and established for owners to credibly approach the debt market with their projects.
  - Assessment of how reliance on capital markets can risk exposing the government to either accepting high credit exposure in case of a large external debt raise by the program owners (using credit guarantees), or a cost of capital for the project (and thus a high cost of electricity).
- Fair remuneration of nuclear capacity and energy in the system as well as nuclear-compatible revenue mechanism can be assessed, developed and agreed:
  - PPAs could be provided by the Swedish state, if so the country would need to agree to either varying levels of price support (a new PPA to be negotiated for each plant or reactor), accept a blended cost of generation for the new plants (with a single PPA negotiated for the whole fleet), or potential merchant price exposure by insulating the plants from market volatility (such as is intended at Dukovany 5 by the Czech government with a take or pay clause).
  - CfDs are commonly used for renewables tender auctions and could be used for nuclear energy as well. However, there is lacking evidence that they have been effective in raising market capital for nuclear newbuild or in remunerating developers or owners for the risks they must take in assuring project development and completion.
  - RAB is considered a cost-effective solution as it provides revenues during construction and direct cost pass-throughs to end users, but it is also for these very reasons that it remains technically and politically complex to implement.
- The government can offer a risk allocation incentive to draw in developers, owners, lenders, contractors and offtakers:
  - Financial players may be unwilling to bear the risk of cost overruns, and the government, in addition to potential credit guarantees, may have to provide additional first-loss tranche funding.
  - Vendors would likely need to be both incentivized to reach the best level of performance and bear certain risks to address disruptions in productivity.
  - Licensing timelines across the design life time and regulatory constraints need to be tackled to optimize program delivery.
- Political risk to be addressed:
  - In the case of a change of policy, the Swedish program could be delayed or even cancelled.
  - By aligning the legal framework with the political ambition of the program, stakeholders will be reassured that the program will proceed. As highlighted before, long-term visibility is key to making this program successful.

Previous cases of GSP in Europe show different ways to address financing but do not reveal a consistent solution to solve the financing gap. Table 4.2 shows such case studies:

	HPC	Sizewell C	PAKS II	Dukovany 5	Flamanville 3	Olkiluoto 3
Country	**UK**	**UK**	**Hungary**	**Czech Republic**	**France**	**Finland**
Project start	2008 (government white paper)	2008 (government white paper)	2009 (parliament-tary vote)	2008 (initial announcement)	2005 (public debate)	2005 (government authorization)
FID	2016	Expected 2024	2015	2024	2006	2003
Construction start date	2016	2025	2024	TBD	2007	2005
Reactor technology	EPR	EPR	VVER-1200	TBD	EPR	EPR
Capacity	3.2 GW	3.2 GW	2.4 GW	1.0–1.2 GW	1.6 GW	1.6 GW
Owner(s)	EDF, CGN	EDF, UK government, TBD	Hungarian government	CEZ	EDF	Teollisuuden Voima Oyj (TVO)
Revenue model	CfD	RAB	Merchant tariff	PPA	Exeltium	PPA
Finance plan	Owner or vendor balance sheet financing	RAB-based with owner or government-backed equity	Host government-backed with vendor-led IGA	Government-backed equity and debt	Owner balance sheet for base funding and SPV non-recourse financing for completion funding	Generator or offtaker cooperative structure (Mankala)
Contingent funding	100% equity, non-committed and subject to caps in the shareholder agreement	Non-committed (constrained by RAB recovery mechanism and investment grade debt covenants)	100% equity	TBD but likely to consist of 100% government debt finance	100% equity, non-committed (the Exeltium SPV not impacted by overruns other than through limited PPA tariff adjustment)	100% equity, non-committed (subject to TVO borrower headroom)

Table 4.2: Case studies on intended GSP to solve financing gap

It is important for Sweden to tailor a complete and coherent financial derisking strategy that complies with the state aid constraints of the European Union, while also maximising the potential cost reductions of the nuclear program through targeted support. Sweden can also benefit from defining its GSP with strategic objectives in mind, with a clear government position on its eventual budgetary constraints and economic imperatives. Private financing can be leveraged instead of public funds, but the likely trade-off is that the state could bear significant indirect costs through guarantees, while not necessarily achieving the lowest cost of electricity because of the higher rate of return demanded by investors. Thus, it would be important for the Swedish government to play a key role in defining what this government strategy should be and quantify it to provide a clear view of the headroom available to policymakers.

Due to the inherent high-risk structure of nuclear projects, the appropriate level of support should be high for the first few projects and decrease over time as the industry matures and delivers cost and risk reductions.

Key takeaways on the role of the Swedish government in nuclear energy funding:

- Interviewees consider the main pre-conditions for market participation in nuclear newbuild to include government policy stability together with a targeted, incentivized and modular GSP, covering any combination of instruments to deliver equity, debt, revenue, risk reduction and investment insurance.
- A clear role for nuclear financing exists for governments which can provide support through five main axes: owner support (equity contributions), lender support, revenue support, project risk allocation and investor insurance (indemnification clauses).
- A business-as-usual market oriented strategy of minimal governmental intervention, was not considered likely by the interviewees, to support the recently announced nuclear energy policy goals.
- Recent nuclear GSPs in Europe do not reveal a clear pattern however, owing to the complexity of the endeavour and the differing risk-taking strategies of the respective governments.

> "
> CfDs can deliver MW, but value is delivered in MWh.
>
> **Government representative**

> "
> Sceptical of CfD as a form of subsidized price protection, capital tends to migrate to countries with higher electricity prices.
>
> **Vendor interviewee**

> "
> There is an apparent need to educate companies on contract alternatives (CfD, RAB, Mankala) in all discussions. Discussions on price level f or nuclear does not cover 'system cost'.
>
> **Industry interviewee**

> "
> The type of revenue model (CfD, Mankala, RAB) is not immediately relevant for institutional investors, it is mainly a consideration of risk and reward on the return on investment.
>
> **Financial investor interviewee**

“

Licensing is considered a significant risk; the process needs to be more p redictable as the present system is opaque.

Shared view between interviewees from investors, operators, enablers and vendors

“

Swedish regulation is officially tech neutral, however the licensing cost is per unit based, regardless of how many have been built before.

Enabler interviewee

“

Sweden and Finland would both benefit from a closer collaboration between STUK and SSM. Have started to collaborate, need to improve. At the same time, it is not expected, or preferred, to aim for a European standard.”

Owner or operator interviewee

“

Prelicensing process should be considered for the future.

Owner or operator interviewee

4.2 Cost estimates for nuclear newbuild

A review of current cost estimates for nuclear newbuild construction demonstrates the big variations across countries, through e.g., supply chain development, and series effect economics that different programs can face, see figure 4.5.

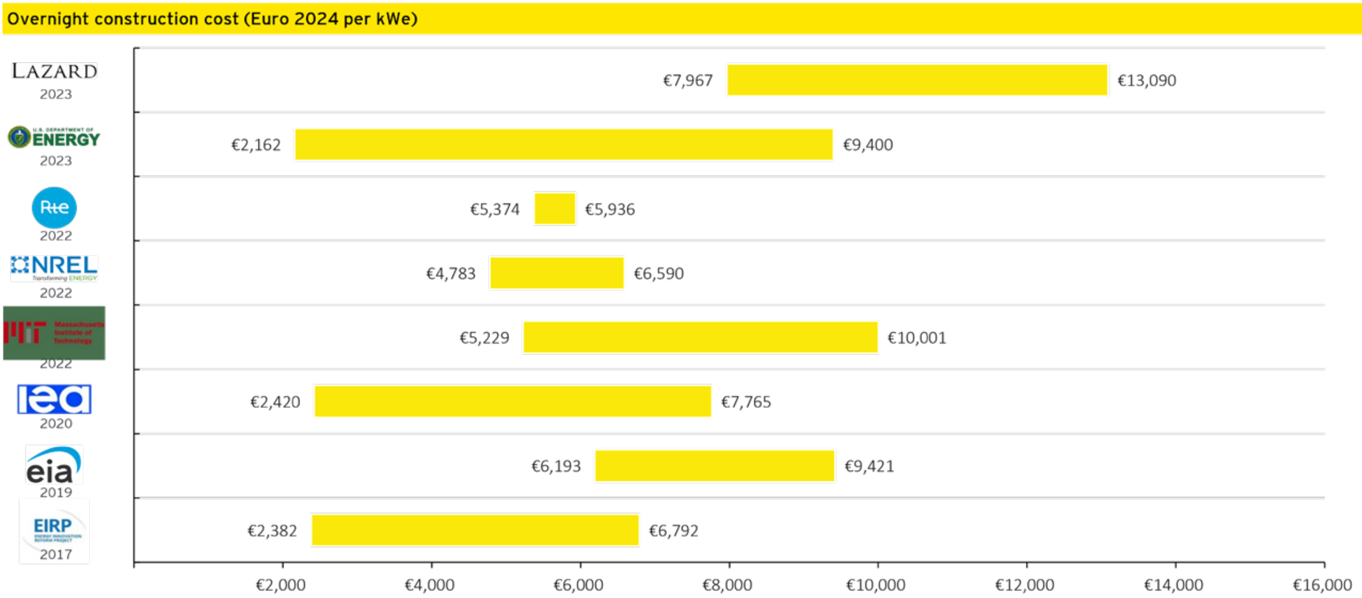


Figure 4.5: Review of current cost estimates for nuclear newbuild construction (€ per kW), data from respective studies.

Figures at the low-end of the spectrum usually reflect South Korea's historical overnight construction costs (as with the US DoE and International Energy Agency (IEA), OECD NEA), while the high-end is based on the costs of programs such as Vogtle 3 and 4 (US DoE, Massachusetts Institute of Technology (MIT) and Energy Information Administration (EIA)), which faced significant issues to reach completion.

The differences are usually due to a combination of changes in mission scope for subcontractors, regulatory changes, challenges in project planning, supply chain issues and delays, as well as FOAK costs related to e.g. additional studies, incomplete design and worksite issues.

For instance, South Korea has been able to leverage its continuous nuclear newbuild experience since the 1970s to accumulate experience and remedy most of those issues over time. Thanks to its learning rate (approximately 15% between 1978 and 2017), the country's nuclear industry has been able to surpass the learning rate achieved by the combined-cycle gas turbine industry (12%) and rival that of solar technologies since the 2000s (20%), see figure 4.6.

The impact of a high learning rate on construction costs can be very significant

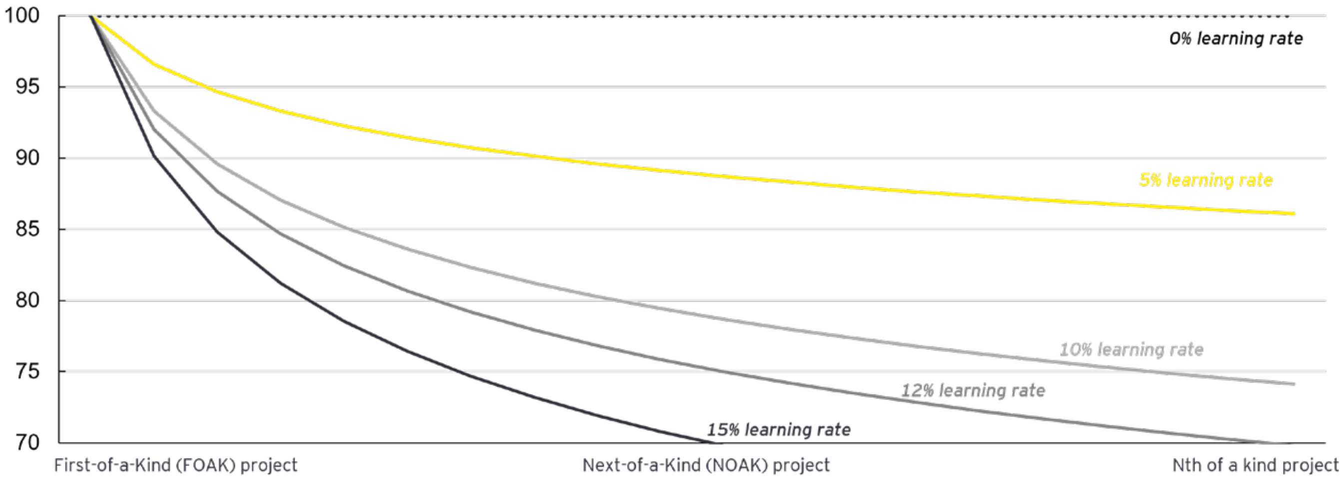


Figure 4.6: Learning rates on construction costs for first-, next- and Nth-of-a-kind projects

Historical precedent in the French program also demonstrated that a second unit at the same site will see overall cost reductions of circa 30% compared with the first unit, so the overall cost of the two units could be increasingly optimized.

The LCOE, a metric used to compare the cost of energy generation at the plant level, can estimate how nuclear is commercially attractive compared to other technologies. As all fossil-free energy sources are needed for Sweden to become fossil-free in line with the government objectives, figure 4.7 shows how nuclear energy has similar LCOE as other technologies. LCOE is computed as the sum of the net present value of all generation costs, Capex, Opex, cost of financing, etc., divided by the unit of electricity generated over a plant's life. Using data extracted from the IAEA for nuclear and hydropower and Lazard for additional, figure 4.7 below depicts the latest LCOE from most electricity generation technologies given various cost of capital estimates.

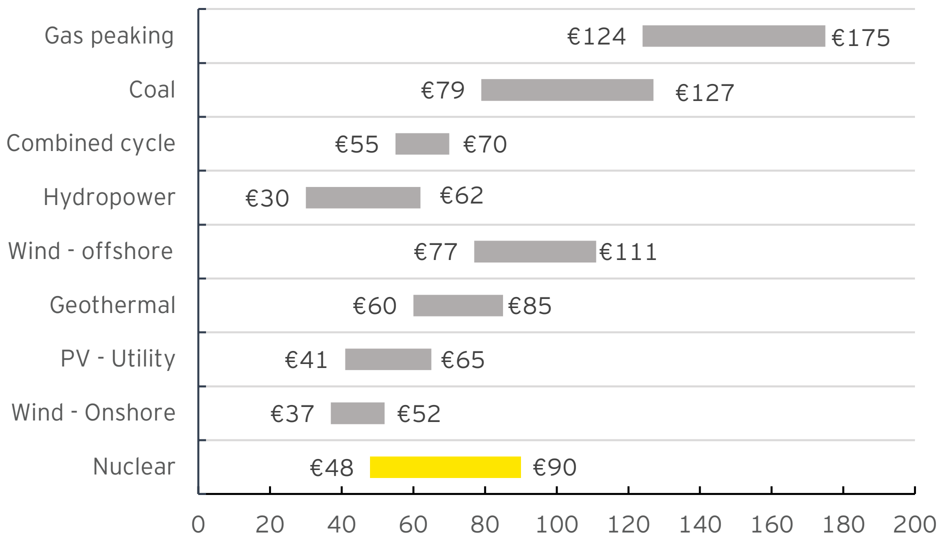
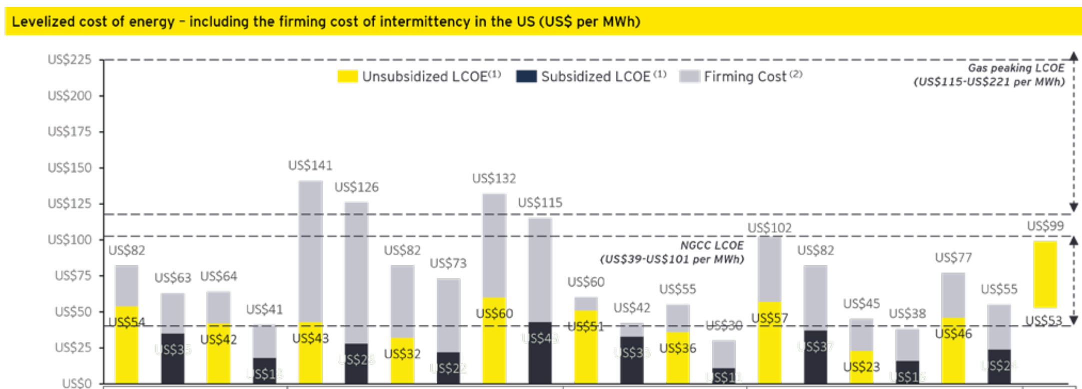


Figure 4.7: Latest LCOE across electricity generation technologies (€ per MWh)

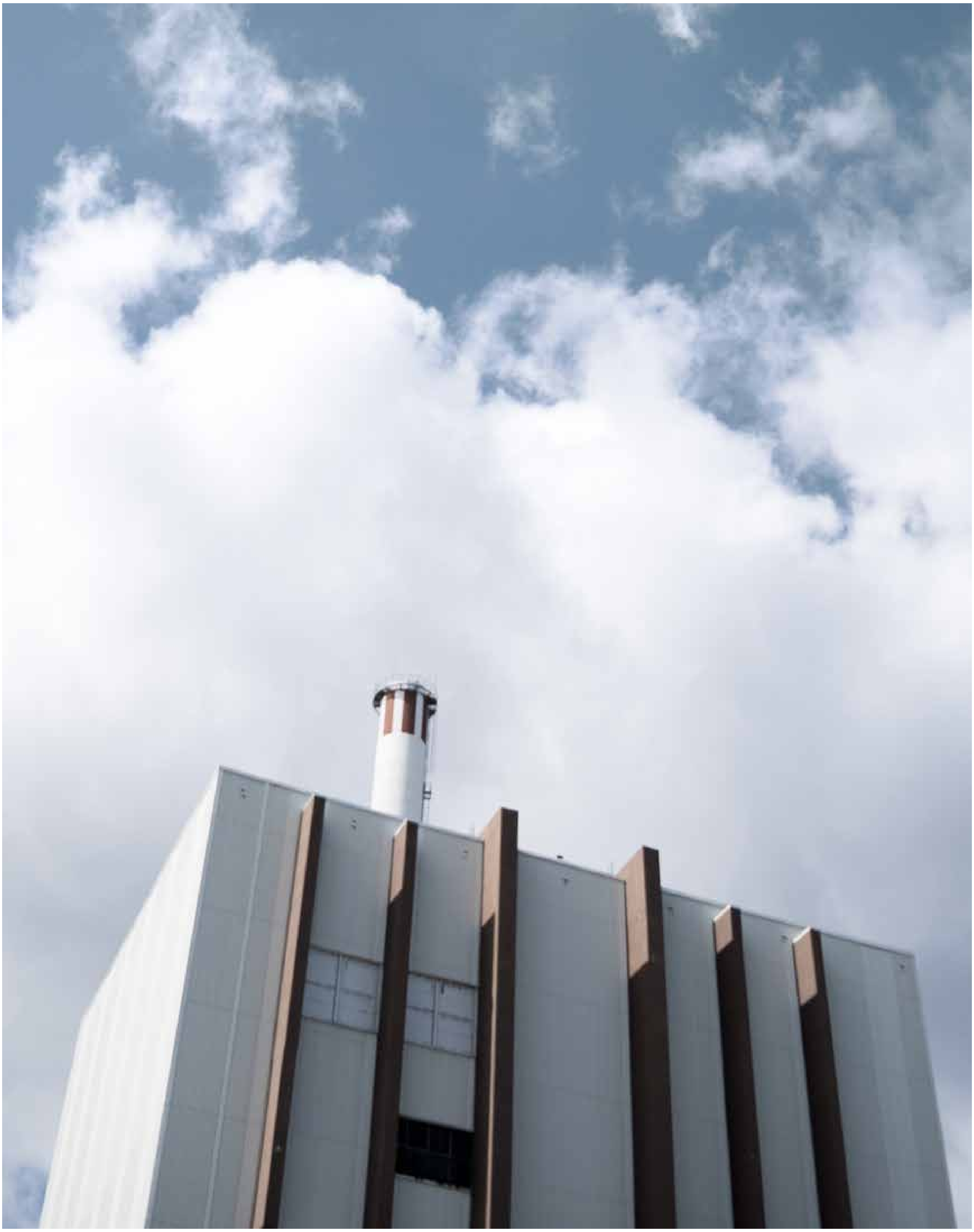
At the low-end (4% cost of capital), nuclear energy is competitive with other low carbon sources, even prior to considering overall system costs, carbon pricing and the cost of firming intermittency for wind or solar power. At the high end (10% cost of capital), the need for nuclear to benefit from a comprehensive derisking GSP is clear, as it becomes comparatively more expensive than other additional sources.

However, while LCOE is useful to compare the cost of generation of technologies, it is limited to a plant-level assessment and does not look at wider economic impacts on the electricity supply system. As such, the cost of firming intermittency of renewables power sources such as solar photovoltaic or wind energy in the US has been computed by Lazard (as seen in the table 4.3).



	Solar	Wind	Solar	PV + Storage	Wind	Solar	Wind	Solar	PV + storage	Wind	Nuc.
ELCC(3)	50%	16%	7%	51%	15%	85%	17%	38%	70%	15%	N/A
Capacity factor	20%	43%	25%	51%	30%	21%	50%	19%	70%	39%	85-95%
Resource penetration	3%	25%	32%	32%	19%	1%	56%	5%	5%	7%	N/A
	Midwest independent system operator		California independent system operator			Southwest power pool		PJM system operator (DC and 13 other states)			

Table 4.3: LCOE including the firming cost of intermittency in the US



Given that the electricity system must always balance production and consumption, the intermittency of renewables poses a challenge in terms of immediate generation capacity when needs arise. Thus, renewables are usually backed up by another source of peaking or load-following power, which can be rapidly mobilised to ensure grid stability. This is a cost which is not captured in the LCOE. Other potential backups exist, such as hydrogen, batteries, or pumped hydro. However, they all come with additional costs (the National Renewable Energy Laboratory (NREL) estimates the cost of a four-hour lithium-ion system at US$245 to US$403 per kWh[50]) and limitations (pumped hydro has a high localised impact on biodiversity, as it functions as a reservoir).

Additional investments in the overall electricity system, such as additional transmission and distribution capacities are usually required as well to ensure grid stability in a high-renewables scenario compared to the current trajectory of the electricity grid.

In 2022, the French Transmission System Operator (RTE), concluded after a year-long research project on the future of the French electricity system that despite the more expensive generation costs of nuclear when compared with renewables, the overall electricity system was much more competitive with a large nuclear footprint[51]. Overall, the cost reduction was estimated to be between 10%–20%, representing savings of €15–20b annually.

A previous study by Confederation of Swedish Enterprise[52] estimated that the system costs for a 100% renewable scenario in Sweden would be around SEK548–SEK752 per MWh, compared to SEK373–SEK473 per MWh in a scenario with a large nuclear footprint (50% of electricity supply). This technology-neutral scenario would lead to lower price volatility, an optimized investment schedule for the grid expansion and lower lifecycle greenhouse gas emissions (10gCO_2 per kWh, vs 16gCO_2 per kWh in the renewables-only scenario).

Key takeaways on cost estimates for nuclear newbuild:

- Government resources can be assessed in the context of the holistic, system-level contribution of nuclear energy to the Swedish economy. A review of total costs, risks and benefits of a nuclear energy program is beneficial to identify market bounding conditions and develop potential assignments for market participants, with associated risk and reward combinations.
- The industry has proven that it is able to achieve important economies of scale given a clear development timeline, consistent government policy, and available capital to finance its projects.
- At a similar cost of capital, nuclear is usually more expensive than renewables as a generation asset, see LCOE chart, but provides stability to the grid, and overall, much lower system costs as demonstrated by the TSO and precedent research released by the Swedish Confederation.

50 Cost Projections for Utility-Scale Battery Storage: 2023 Update, National Renewable Energy Laboratory (NREL), 2023
51 L'Analysé Éconnomique 11: Un chiffrage des coûtes des scénarios pour comaprer les différentes options, (rte-france.com) (in French)
52 Kraftsamling elförsörjning, Scenarioanalys 2050, Qvist consulting, 2022

4.3 A clear industrial policy to ensure supply chain support

With the stated program development ambitions, considerable industrial capacity needs to be incorporated in the Swedish supply chain to meet the domestic demand generated by nuclear newbuild.

Currently, Sweden possesses an existing ecosystem of nuclear energy suppliers that could support the program. Uranium mining, conversion and enrichment do not take place in Sweden. A fuel assembly facility, owned by Westinghouse, is located in Västerås but it does not supply the entirety of Sweden's current needs, which are supplemented by other vendors outside of the country.

Three nuclear power plant owners co-exist today, with Vattenfall (majority owner of Forsmark and Ringhals) and Uniper having no recent experience in developing and constructing nuclear, while Fortum is a minority shareholder of TVO which developed Olkiluoto 3.

Thus, numerous parts of the Swedish supply chain will need to gain experience in the future, including forging companies (which design the boilers used in nuclear power plants), welders, construction, and engineering companies, steelmakers, nuclear concrete makers, mechanical module designers and makers, etc. Compared to the last nuclear era in the 1970's, the international content in the supply chain for the new nuclear will increase compared to last time if not reestablished, leaving certain parts of the required skillsets located outside of Sweden.

While localization opportunities remain, this should be a long-term objective with progressive step-up of the Swedish supply chain. Construction of the first nuclear power plant will probably require a contract for the nuclear island involving a foreign vendor. Local supply chain can come in support for civil works and the balance of the plant.

As its experience grows, a localization strategy can be put in place, notably given the potential size of the Swedish program. Localization has been successfully implemented in multiple countries, such as France, Japan, Korea and China (see figure 4.8).

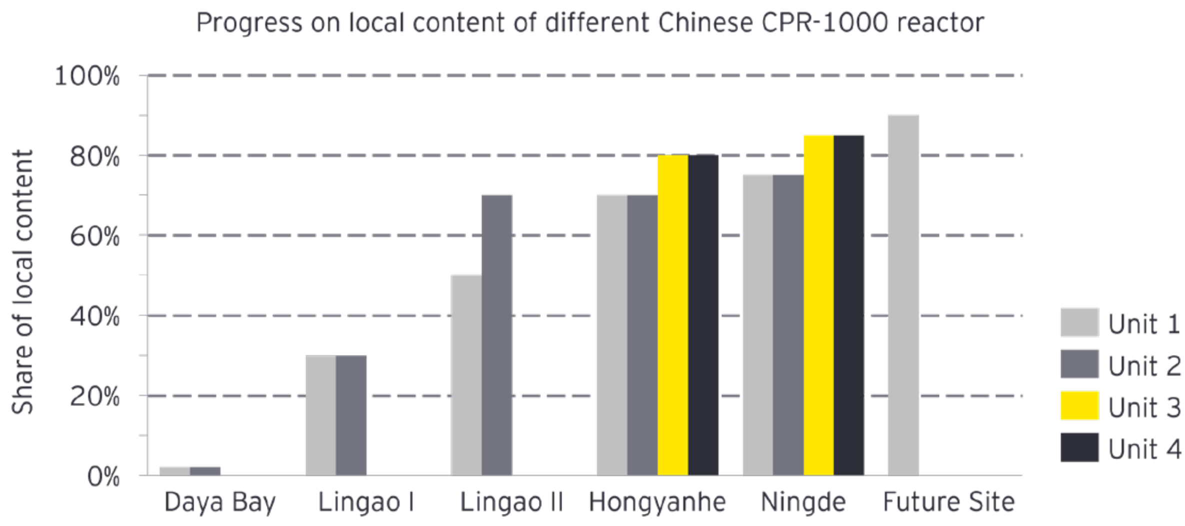


Figure 4.8: Progress on local content of different Chinese CPR-100 reactors

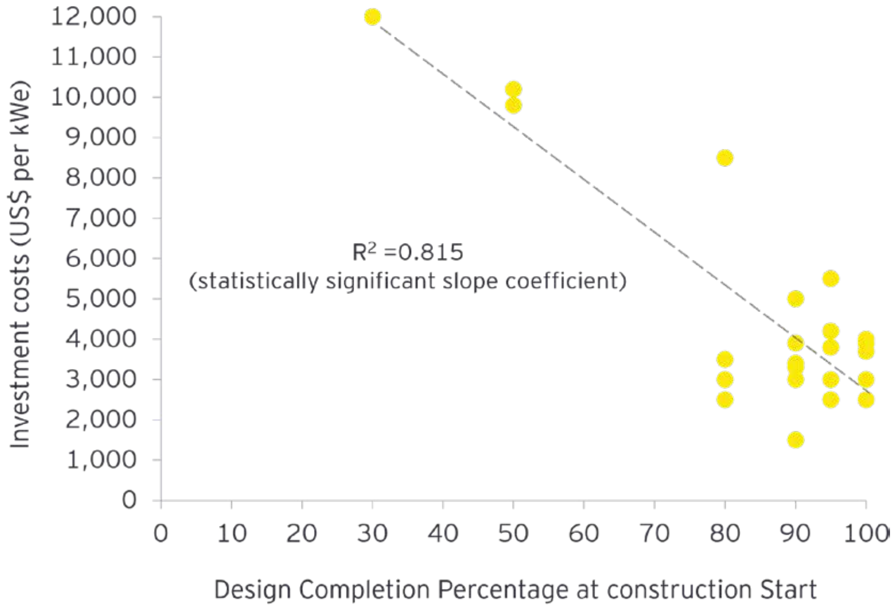


Figure 4.9: Percentage of design completed and total capital costs

As mentioned before, industrial mobilization will be key in ensuring that the program reaches a sufficient level of maturity to attract private capital. In Russia, the long-term development program of the industry, which included over 30 projects at home and abroad, has strongly benefited the national nuclear vendor Rosatom, with overnight cost of construction which are on average 54% lower than those of the OECD average according to an IEA study[53].

This has been achieved thanks to a constant inflow of new projects, which allowed Rosatom to improve its products and processes continuously over the years, thereby driving costs reductions. During the various phases of project development (from predesign to procurement and construction), long-term industrial mobilization enabled considerable refining of the nuclear delivery and supply chain[56].

Indeed, the maturity of the design and supply chain is one of the key cost determinants for the project. For large-scale infrastructure projects, cost estimates can be subject to strong optimism bias in the early stages of the project design[54]. Recent cost estimates for recent nuclear newbuilds exemplify this point clearly:

- Overnight construction costs for the AP1000 at Vogtle 3 and 4 increased from US$2,000 per kWe to above US$10,000 per kWe today.
- Project cost estimates for NuScale went from US$5,300 per kWe in 2020 to US$20,100 per kWe in 2023.
- Overnight construction costs for the EPR at Flamanville went from €2,000 per kWe in 2005, to approximately €9,000 per kWe today.

Thus, it is critical that the design of the plant be completed prior to construction start. Research carried out by the Energy Technology Institute[55] demonstrated that a lack of design maturity was one of the major causes of cost overruns and delays. Figure 4.9 demonstrates the correlation between the percentage of design completed, and final investments costs per Gen III plant.

53 Projected costs of Generating Electricity 2020
54 Understanding cost growth and performance shortfalls in pioneer process plants, Merrow, Phillips, Meyer, 1981
55 The ETI Nuclear Cost Drivers Project, Energy Technology Institute, 2020

As stated by numerous interviewees, involving an existing supply chain at an early stage would likely allow Sweden to gain some high added value activities, but at the probable cost of design maturity. New technical standards must be applied, researched and manufactured by suppliers who do not yet benefit from recent accumulated project experience.

Nonetheless, prior solutions adopted to localise a progressive share of content could be studied. In China, local content for the future CPR-1000 reactor when it was introduced at Daya Bay in 1987 was nearly non-existent. That proportion was increased to 30% for the Next-of-a-Kind plant at Lingao I in 1995–1996 and reached around 85% at Ningde in 2008. Over 20 years, China, thus, charted a course for progressive indigenization of its supply chain, while leveraging the options from the international supply chain.

Since 2010 at Akkuyu in Turkey, Russia has begun to create a systematic process of audit and review of potential manufacturers and suppliers, to test a potential adaptation to the local content. While the ongoing process has elaborated a detailed plan of localization resources, around 7,500 items have been identified for monitoring in Turkey, and key partners are approached with an open dialogue to expand the pool of potential resources to be put to the project.

Recent experience in Europe and the US has been addressed previously in section 3. However, interviewees insisted on certain key takeaways from those case studies. EPR projects were built on an eroding base of competence and capabilities across the supply chain, with an ageing workforce and a shrunk supply base. Over the last 20 years, the European supply chain revival has been significant, but major challenges could still arise in the future. Similarly, AP1000 projects had to create a new supply chain in the US and internationally to support the growing needs of Vogtle 3 and 4. Frequently, the companies in that supply chain had limited experience in the nuclear sector and had to learn new construction techniques while the project was ongoing.

Key takeaways on a clear industrial policy to ensure supply chain support:

- Interviewees believe that the Swedish nuclear energy supply chain benefits from capable and experienced players across the supply chain. However, the lack of regional experience in newbuild over the last 40 years will require ramp up activities.
- Academic research has linked supply chain and design maturity to large-scale infrastructure projects being close to on-time- and on-budget delivery. Recent experience in Europe and the US demonstrates the lessons that need to be (re)learned by players that have not been involved in previous nuclear energy projects.
- Thus, Swedish policymakers may consider enablers to help both nuclear generators (including supply chains) and offtakers in a comprehensive industrialization policy that rewards long-term localization strategy, while leveraging the existing international capabilities and resources that are on the critical path of a fast, sustained and cost-competitive decarbonized economy.

5 Conditions for successful nuclear energy project development

The broad view from interviews with Swedish Enterprise's members is that Sweden possesses a wide range of possibilities to achieve nuclear deployment at the scale targeted by the government. Thanks to its decade-long experience in managing, developing and improving nuclear energy assets, along with latent demand for additional baseload electricity from energy-intensive consumers, decarbonization targets and broad public acceptance,[56,57] the Swedish market is uniquely positioned to deliver nuclear newbuild more competitively than in several EU markets.

On the other hand, EY was consistently reminded by the interviewees that Swedish electricity prices have been comparatively lower than in other European countries for a long time and the energy-only market design does not fully support the higher capital recovery required for nuclear newbuild relative to other technologies. The historical investment model for Swedish generation, including nuclear, provides a helpful template for the next phase. Vertical integration of nuclear supply offers real-time alignment, and transmission of, the costs and benefits of nuclear, between the generators and the offtakers.

But unlike the inaugural nuclear investments in Sweden, it was pointed out in the interviews that the owners and offtakers are currently in full competition with other utilities and generators for consumers, which is consistent with the EU third package and competitive market unbundling requirements, as well as EC state aid restrictions. Competition for load was said to be damaging[58] to the historical nuclear business model as new generation (mostly renewable energy), have been granted priority dispatch together with price support. This has had the effect of driving down market prices for nuclear generation (which as baseload units are market price-takers) and cannibalising large baseload blocks of power that previously could be reliably met with nuclear production.

Interviewees recognized that Mankala or cooperative approaches have not been widely tested in competitive market conditions for nuclear newbuild other than Finland's Olkiluoto 3. Since Sweden's existing nuclear owners are large corporate utilities with limited capacity to pass newbuild outturn cost and delay risks to their customers, the historical approach to investment on cooperative principles with captive or price-taking consumers was stated to pose significant risks to nuclear newbuild generators in Sweden.

The EY organization heard wide recognition that the preconditions for nuclear deployments or investment are either fully met or considered achievable for the 2035 and 2045 milestones, notably:

- Nuclear infrastructure meeting international best-practices with respect to the IAEA's 19 issues, including safeguards, security, safety, radiation protection, environment, etc.
- Public acceptance (albeit more from a safety or environmental, rather than economic, perspective).
- Existence of three international-scale nuclear owner or operator organizations.
- Predictions of robust and rising long-term base-load energy demand as Swedish industry decarbonize their processes.
- Strong interest from developers, vendors and supply chain partners.

In interviews with the financial community, there was an understanding of the broader value proposition of nuclear energy, even if financial institutions remain relatively inexperienced in financing nuclear assets themselves. Lenders pointed out that nuclear projects have not been "naturally occurring" in competitive markets, and that commercial nuclear projects require some form of government involvement. In recent decades, there has not been meaningful commercial financing of nuclear power plants unless significant public support has been provided. For instance, the financing of Olkiluoto 3 was made through a combination of the French Export Credit Agency (ECA) support and a syndicated pool of commercial banks that were incentivized to finance the project by the implicit backing of the French state through the ECA in support a turnkey nuclear EPC contract from a state-owned vendor.

56 Presentationer | SOM-institutet, Göteborgs universitet (gu.se)
57 Svenskarnas stöd för kärnkraft håller starkt, press release, Vattenfall, November 20 2023
58 Economics of nuclear and renewables – ScienceDirect

> We are interested in supporting the energy transition and supply of Sweden through nuclear, but we have yet to look at specific project risks.
>
> **Financial institutions interviewee.**

> It is absolutely key to get bipartisan agreement on the future of the electricity system in Sweden prior to launching new nuclear. We are not certain how to ensure the stability of the electricity system, but we will work on financing the future energy supply to meet the growing industrial demand.
>
> **Financial institutions interviewee**

Governments were encouraged by the ECA to recognize and address the specificities of the nuclear business model at the project level, including:

- A delivery model featuring multibillion upfront costs, a multiyear schedule and significant risk of cost overruns
- Complex project interfaces amongst main role holders across asset lifecycle (vendor, contractor, owner, site owner, operator or licensee, safety regulator, end users and multiple government oversight bodies)
- Long asset lifecycle (up to 80 years) providing benefits beyond the financial horizons of "mortal" commercial sponsors or owners

In the context of competitive supply conditions in a short-term energy-only market the long-term value of nuclear generation is at risk of not being monetized, restricting lender and investor appetite for nuclear newbuild.

Thus, the ambition of any supporting government should be to bring to life an asset that will be beneficial to its long-term strategy, while ensuring the cost-effectiveness of its backing. While it was stated in the interviews that, technically speaking, Sweden could fund the entirety of the nuclear program on the government balance sheet, this would signal a form of renationalisation in the energy market and lead to a potential eviction effect of commercial-level returns and private investors. From a public acceptance standpoint, the potential absence of private investors in nuclear newbuild was seen as detrimental to the industry and the government's ultimate investment targets.

Interviewees shared their views that the success of Sweden's new nuclear energy program would rest on making it bankable (i.e., capable of drawing in external financing in both debt and equity) and economically competitive against other technologies. This was stated to be achievable by ensuring that any government support would be carefully targeted and optimized to ensure that "normal" risks, and returns, are transferred to the private sector.

Interviewees referred to the recent experience of nuclear newbuild and existing literature[59] highlighting FOAK risks. Interviewees referred to FOAK in connection with both nuclear design and mega-project risks. The EY organization heard that the private sector would likely to support investments featuring FOAK risks, but their appetite for nuclear investment would heavily depend on the credibility and effectiveness of the derisking process. It was further shared with the EY organization that the government would be expected to play an important role in the derisking process. Once further experience has been accumulated throughout the supply chain and a clear deployment schedule given industry could be expected to deliver efficiency gains.

The most critical phases with high risk assigned to them in such developments were the ones covering the development phase, leading up to the final commissioning of the plant. Some investors (financial and utility) indicated that certainty on completion funding would be a critical feature in any significant, initial nuclear investment they could undertake.

59 Nuclear energy market consultation, KPMG, July 2021

Interviewees considered the potential conflict for government in eventually acting as a funder (including, potentially, funder of last resort) without possessing the full skills, capacities or mandate to deliver the construction, engineering and procurement of a nuclear power plant. Government was recognized to have to rely on specialised contractors for the various subsections of the project that include e.g. the procurement of nuclear technology, civil engineering, and plant build. Thus, the area where policymakers can be the most effective is in the setting overall policy in the lead up to plant construction, and support in establishing favourable regulations and licensing processes for new nuclear. Special care would therefore be required in project structuring, contracting and procurement, to ensure that the private sector participants were properly incentivized through exposure to both upside and downside returns. Many interviewees shared their belief that their organization would be more concerned about losing their investment than about potential variance in their rate of return (return of capital first, return on capital second).

In its National Infrastructure Development Program (NIDP) guidelines, the IAEA created a multiphased approach for governments seeking to support nuclear power (as seen in figure 5.1).

Despite its maturity, post-Phase 3 or Milestone 3 overall status, like other "recomers," Sweden sits broadly in the Phase 1 (preproject activities) where it may need to gather a certain level of program definition to reach a lasting commitment to nuclear with the private sector. To progress on to the next phases and reach the FC or FID stage, the Swedish government was encouraged in the interviews to address the risks associated with the following issues:

- What are the preconditions that need to be addressed to make a nuclear energy project reach financial close?
- How to identify and empower the entity which will lead the project through its development phase?

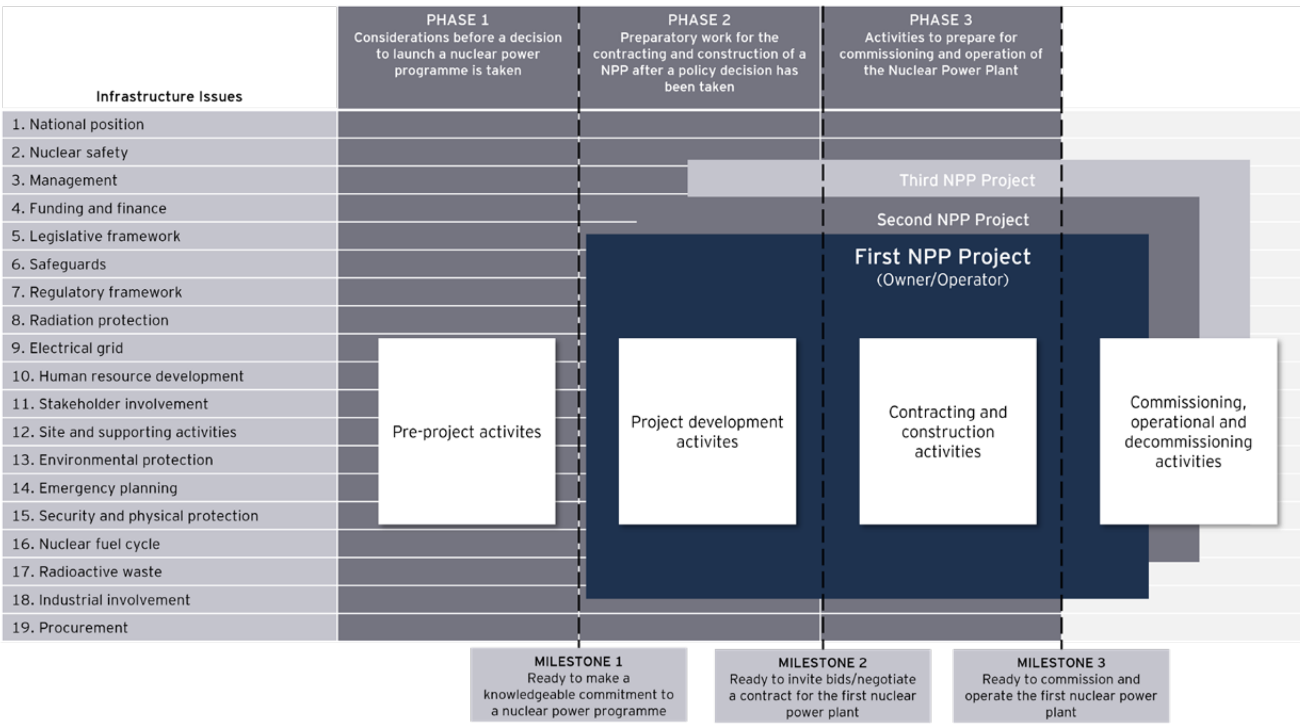


Figure 5.1: National Infrastructure Development Program

5.1 Definition of a new Swedish investment model

Due to the existing nuclear financing gap, interviewees saw government as the appropriate body to orchestrate a financial derisking process that would credibly act to identify, reduce and ultimately disperse risks to actors across the project and program who are best equipped to handle them in their normal business operations. This would ensure that a higher level of clarity exists for all stakeholders on their expected level of exposure throughout the project development phase. Certain interviewees referred to "project assignments," e.g., the specific role(s) they could be offered and expected to undertake in their normal course of business.

This clear allocation of risk will be the basis for project bankability leading up to FC or FID as project definition will have to be as complete as possible before the specialist organizations leading in project development and delivery and their capital providers, feel comfortable supporting a nuclear newbuild.

The Swedish government's task was widely seen as needing to plug the gaps of the remaining risks by targeted financial support through a tailored GSP. Across the interviews, several key areas for government support emerged from the following questions, visualised in figure 5.2:

- Delivery model: What kind of contracting approach and partnership to plant delivery is feasible and competitive between the owner and the delivery partners? Is a technology competition strictly necessary among FOAK projects for government to achieve value for money?
- Ownership model: How can plant economic ownership be incentivized? Can different classes of ownership help attract market investors? Is there value in dissociating financial ownership from the operations or licensing accountabilities of the plant?
- Operations model: Which actor will have the voice of the operator during the pre-operational phases and will take over and operate the licensed plant once it is online? What incentive model best balances the operator's mandate to maintain licenses, including for nuclear safety, with the requirement of capital recovery for the financial backers at reasonable return levels?
- Back-end model: How should spent-fuel long-term disposal and decommissioning costs and liabilities be managed? What long-term policy objectives should the government signal to the market? Is the current regime sufficiently apolitical and therefore investor friendly? Given numerous promising technical innovations with respect to fuel re-use and deep geological disposal or storage, how can government incentivize investment today whilst keeping the door open to further innovation in the industry? Would the EU agree to any such model from a state aid perspective?
- Revenue model: What remuneration mechanism(s) are appropriate to compensate nuclear plants, essentially "who is paying for what, to whom, when and under which pre-conditions"? What are the reasonable bounding conditions for Swedish end users and do they know themselves? What are the appropriate end user metrics to assess nuclear competitiveness? Is that per-kWh price to beat, emissions levels, reliability levels, capacity equivalence (including duration), cost- and dispatch-predictability, etc.?
- Financing model: What sources and structures of financing are feasible to deliver liquidity at competitive costs throughout the asset life, from early development to operations and decommissioning? What project structures can best deliver the ample liquidity required for nuclear newbuild whilst assuring incentives among the project parties, including the financing parties?

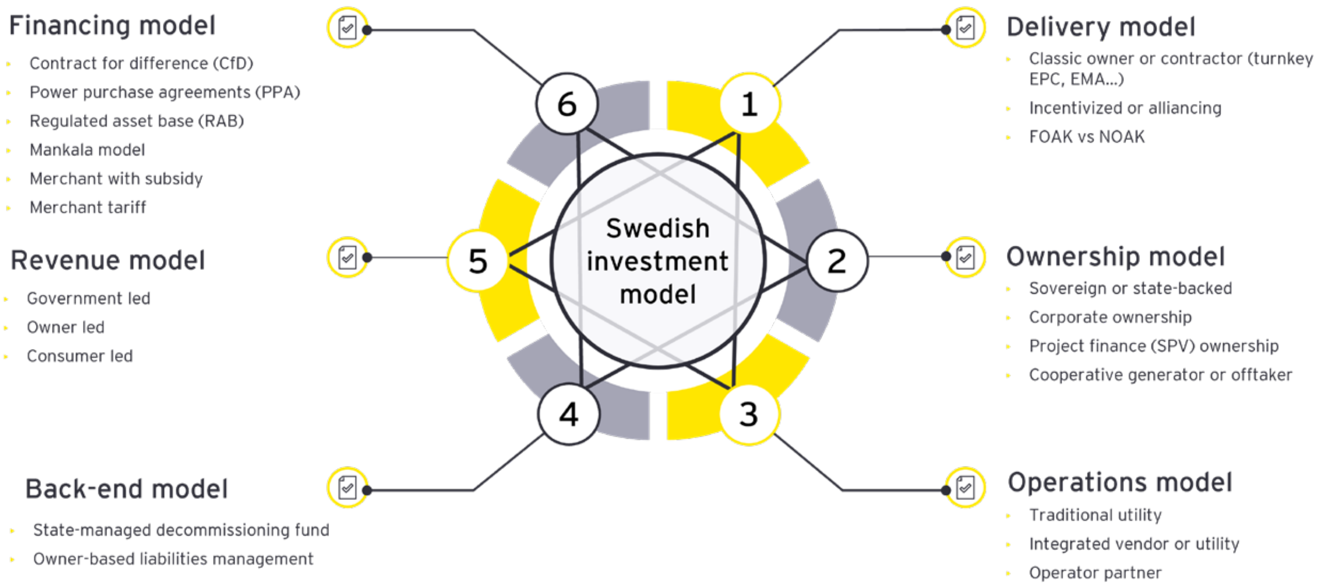


Figure 5.2: Proposed investment model for nuclear newbuild in Sweden

The government support package can be extracted from the investment model as the degree of government involvement is materialized by the chosen options from the list above and figure 5.2. The investment model will inherently define the role of the taxpayer, what government instruments can be deployed and what overall value-for-money proposition the project developer is setting forth.

The government can use the investment model to develop a modular, technology-neutral package that would allow any developer, investor or vendor to compete on its unique strengths while having confidence that specific, pre-identified gaps in its business model can reasonably be plugged. The GSP could also be structured and incentivized to ensure that nuclear investment support does not become a form of "corporate welfare" (i.e., support levels fall away and the government evaluate proposed GSP decline rates of each developer).

These multiple project interfaces with government were stated to be necessary to assure investability and economic equilibrium. Equally, interviewees recognized that the eventual GSP offering should be vendor neutral to draw in the widest possible interest from nuclear technology providers once a selection or tendering process is launched.

Interviewees referred to various solutions for each of those models, as follows:

	Key objective	Potential options
Delivery model	Identifies and defines the pre-conditions for financial close	**EPC turnkey model:** A single contractor or consortium of contractors takes the overall responsibility for the work, usually with price guarantees. **Split package:** Overall responsibility is split between various contractors, usually with the nuclear island delivered by the nuclear technology vendor and the conventional package provided by another contractor. **Multi-contract:** Overall interface management borne by the owner with different contracts for different categories. Under any delivery contract structure for "first-in-a-while" units, incentives and partnership principles can be more economically effective than the turnkey, fixed-price delivery contracts that typically support more mature, replicable construction projects. Thus, delivery costs and risks for nuclear cannot be expected to be shifted or shiftable entirely to the delivery partners and supply chains, until there is more predictability in outturn costs, schedules and unit performances, making the delivery model an important unknown variable in the current nuclear newbuild financing context.
Ownership model	Identifies and defines the asset owner and ultimate client or counterparty of the delivery partners, regulatory authorities, offtakers and external financiers	**Sovereign ownership**: Such a model relies on governments directly owning either the plant, or the SPV that is used to fund the plant. **Corporate ownership**: The model relies on private sector entities to own the plan or the SPV that manages it. Corporate ownership can take multiple forms such as Mankala (using the electricity end users' balance sheet) or existing nuclear owners in Sweden. **Project finance (SPV) ownership:** The model is based on the capacity of the plant to raise external finance with limited-recourse facilities. This is based on the project intrinsic cash flow generation and risk profile. The existing Swedish ownership model, reflecting vertical integration between generation owners and offtakers, may be replicable for newbuild. However, for reasons described above, the balance sheet strength and corporate finance strategies of the existing nuclear utilities are not as conducive to nuclear newbuild investment as they used to be (premarket unbundling). Furthermore, the existing ownership model may need to be revisited if new types of investors are to be attracted to nuclear generation.
Operations model	Defines and identifies who will operate the plant and bear operational risk	**Integrated owner or operator:** The existing owner of the plant will take full operational control of the plant. **Separated owner or operator:** The financial owner and plant operator are separate entities. This model is relatively new or emerging and can enable plant ownership and financial structures that are not symmetrical with operator ownership structure.
Back-end model	Defines and identifies the requirements for funding of nuclear-specific liabilities (in particular spent fuel management or disposal, decommissioning) consistent with overall asset investability and bankability requirements	**State-managed decommissioning fund**: The state, through a dedicated fund which collects payments from the plant, will invest and save the appropriate amount of assets to face upcoming liabilities. The risk is borne by the state in case of overruns. **Owner-based liabilities management:** The owner of the plant saves a specific amount as a share of its revenue to face long-term decommissioning obligations. The owner bears the risk in case of overruns. **Existing nuclear waste fund:** The existing KAF fund receives and manages the fees paid by nuclear power companies to finance the future costs of managing and disposing spent fuel and waste products. The overrun costs are borne by owner or operators.

	Key objective	Potential options
Revenue model	Identifies and defines the remuneration mechanism for nuclear generation, monetising for the generator the full life-cycle benefits	**CfD:** Public law contract where the state and the owner agree upon a fixed price for the power produced at the plant. **PPA:** Private contractual agreement between either the state and the owner, or the owner and offtakers. **RAB:** Public law contract where the state agrees to reimburse capital costs incurred during the project construction and operation, with an additional fee to compensate capital providers for the risk taken. **Mankala model:** Cooperative revenue model where the offtakers of the plant are also its owners. This removes revenue volatility risk from the project and enables a low cost of capital. **Merchant tariff:** A revenue model where the output of the plant is entirely sold on the market, which leads to a significant or full exposure to electricity market prices. This exposes the plant to potentially high revenue volatility and has not proved to be a bankable model for energy generation recently. **Emissions-avoidance certificates:** A premium paid to generators of low-emission power such as nuclear. Investors and lenders have experience with various revenue models across most conventional (non-nuclear) technologies, though each model has presented at times significant issues with respect to bankability and investability. These mechanisms have also been adapted for nuclear transactions in the US, France, UK, Finland and some are being proposed in EU newbuild markets e.g., the Czech Republic and Poland. The success of nuclear revenue models in bringing investment forward has not been strong to date, and the Swedish government would likely need to design a nuclear revenue model that is compatible with the Swedish power market.
Financing model	Identifies and defines the sources of capital that will reasonably be deployed for the project to achieve FID and successful commercial operation date (COD)	**Government led:** Support for financing can be provided as part of the ownership structure through an equity stake or public loans and be led by a dedicated government unit. **Vendor led:** Funding can be provided by the technology vendor through either direct equity stake in the project (as was done at Barakah by Kepco), or by mobilising the ECAs from various countries to provide a part of the debt funding. **Owner led:** When the owner of the plant has sufficient resources at its disposal, it can raise the necessary financial package on its own and provide a joint debt and equity support. As described above, the corporate finance model is not appropriate in current market conditions for nuclear newbuild.

Table 5.1: Overview of nuclear management and financing models

Some combination of the different models listed above are believed to allow nuclear projects to achieve FID, using Swedish conditions and context, and enabling private sector investment. The role of the Swedish government would then be to identify what GSP parameters would be necessary and available for developers to draw upon to address their unique gaps.

Financing being one of the longest lead items in nuclear energy project developments, developers would be expected to focus on their respective GSP requirements in each of the relevant areas. Orchestrating the process, government would be in a position ultimately to define the terms of the generic GSP that would be offered to the market.[60]

This approach was recognized by interviewees as a way to provide clarity on what risks market players are exposed to, enhancing bankability as financial risk and reward assignments are defined and allocated under a comprehensive investment model. With the aim of maximising private sector investment, this was seen as a cost-effective method to ensure project assignments and their associated risks and rewards could be fully underwritten between the market and government, in any number of competitive combinations.

Using the GSP framework below, it is possible to design a theoretical financing plan that would bring together both the investment model limits (i.e., the maximum available private sector participation) and their calibrated GSP response. Figure 5,3 illustrates the components of a comprehensive financial package with shaded areas representing the share of risk borne by a government at different stages of a program, addressing shortfalls in equity and debt for a theoretical project. The remainder of the pentagram is the share of risk covered by market players.

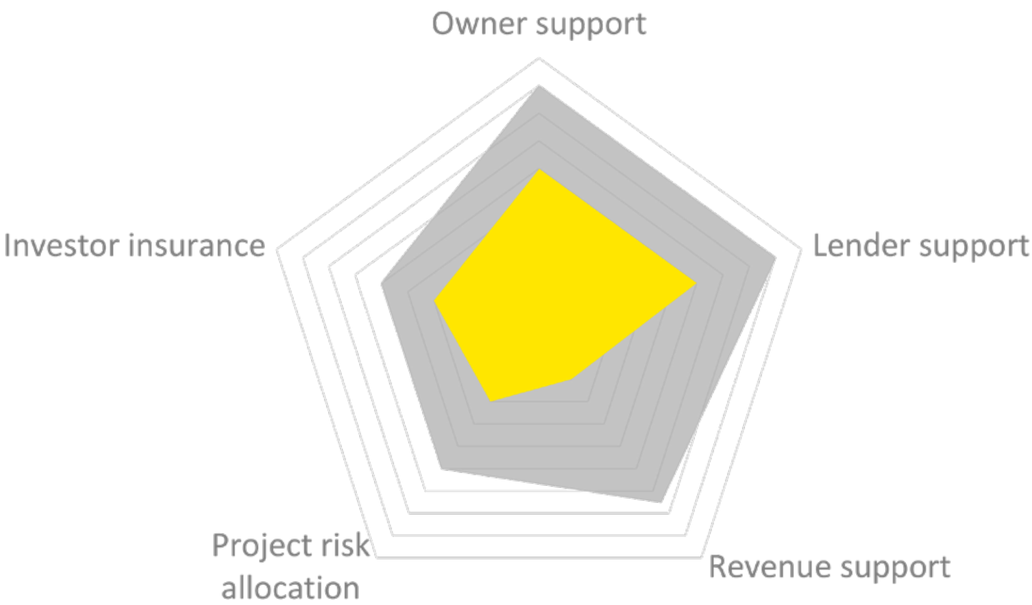


Figure 5.3: Illustrative overview of two examples of government undertaking (shaded areas) compared to the remaining risk and cost borne by the market players at different stages of a program.

60 Responsibilities and Functions of a Nuclear Energy Programme Implementing Organization, IAEA Nuclear Energy Series No. NG-T-3.6 (Rev. 1)

Recognizing that there may be no one-size-fits-all financial package design appropriate and adequate for every project type, interviewees anticipated that the Swedish government would iterate its level of support over time, dependent on the models that are chosen in each of the sections of the Swedish investment model. The Swedish government support would be expected progressively to fall away in scope and quantum as the nuclear energy program approaches successive FID milestones.

For instance, a cooperative model would not necessitate a direct government intervention in the revenue mechanism (as that is provided for in the Mankala arrangements) but could benefit from a supporting government initiative on the financing in debt and equity. Olkiluoto 3 received an ECA loan from Coface (now Bpifrance) and raised additional commercial finance its Mankala-backed investment grade rating. Interviewees recognized nonetheless that the Olkliuoto 3 project may have benefitted from project-specific advantages, such as EPC conditions and commitments, that may no longer be available in the market.

The financial conditions at which the project will be supported would be the output of the financial derisking phase that is undertaken in this investment model. This approach was recognized to enable the nuclear industry to achieve some adequate level of scale, and thus certainty on costs, schedules, unit performances etc. Interviewees referred to the early 2000s and the deployment of renewable energy sources in Europe that were widely supported by public subsidies and revenue support mechanisms. This policy-led approach enabled cost reductions, improved performance and innovation, including localization, over time. While the initial projects were not necessarily considered financable on a commercial (full private-sector risk) basis, renewables are now commonly financed by private players, thanks to the significant amount of experience that was accumulated in the last decades. Interviewees distinguished between direct subsidies, such as revenue support and capital support, and indirect subsidies, such as priority dispatch, waivers on grid connection agreements and expedited consents or approvals.

Additionally, different types of technologies were recognized not to benefit from the same kind of financial support. LTOs can be managed by the private sector, as banks and owners have experience in financing those operations. Large reactors and SMRs or AMRs will also likely have different types of government support attached to them, as they provide different services and present different kinds of risks.

Some interviewees indicated that an important role that needs to be defined is that of the entity which will oversee the project through its development phase. While often underestimated by the industry previously, it was shared that this role has emerged over the last few years as the cornerstone upon which projects should perhaps be lead. They shared their belief that recent project challenges, including some of those highlighted in section 3 of this report, were linked not purely to challenges with the investment proposition but also to an inefficient delivery model, whereby task allocations during the development phase were unclear, necessitating additional resources for unexpected iterations of the business plan across stakeholders. The absence of strong project sponsorship (whether by government, private sector, or a hybrid developer organization) was identified as a possible root cause of failure in the development stage for these projects.

For example, projects such as Flamanville 3 had an unclear governance,[61] with unclear project management governance, and competing priorities which played against the typical strengths of an integrated utility like EDF. Indeed, developing a nuclear power plant project is a complex undertaking requiring long-term commitment. The necessary institutional, human and physical infrastructure to license, construct, operate and develop the nuclear power plant must also be built.

By creating an organization in charge of coordinating the efforts of the many companies and individuals considering nuclear energy, the Swedish government could provide a major form of support for the development of nuclear energy in the future.

61 La construction de l'EPR de Flamanville, Rapport Folz (2019)

Key takeaways on definition of a new Swedish investment model:

- Interviewees indicated that Swedish policymakers may need to assess what the available options are to bring a nuclear project to financial close with a high degree of certainty, leveraging the existing strengths and weaknesses of the existing supply chain locally and abroad.
- This may include providing visibility across a number of critical economic foundations to establish project investability and bankability, including:
  - Definition of the shape and structure of the future contractual relation between the consortium which will develop the project and the owner of the plant.
  - Definition of who the ultimate owner(s) of the program will be and identify the potential financial capacity that they will bring.
  - Definition of how the financial structure of the nuclear project will be built, using either vendor, owner, or government support to the project.
  - Definition of how the project will generate sufficient and predictable cashflows to support its profitability and bankability.
  - Definition of who will manage the plant and ensure the best possible level of performance during operations.
  - Definition of how the management of decommissioning and spent fuel liabilities will be managed.
- The Swedish government could then be expected to calibrate its GSP to address potential shortcomings seen in a combination of those different asks. The GSP should ultimately be seen as the last resort measures through which the project will achieve financial close.

5.2 Definition of a new Swedish developer model

Interviewees affirmed that, to lead a nuclear power project to completion, there needs to be a clear leadership role attributed throughout the various phases of development. As seen in the illustration (figure 5.4), prior to pouring of the first nuclear concrete, a wide number of milestones and issues need to be addressed.

Previous section highlighted how to provide a clear vision on how to reach financial close by answering key bankability and risk issues from a financial perspective. This part of the solution is the creation of an investment model, which solves for FID, but not for development risk.

To provide an answer to this specific risk, the creation of a developer model led by a nuclear energy programme implementing organization (NEPIO) would be efficient for solving the program-level and project-level issues (including those identified by the IAEA in its Milestone approach) prior to FID. As seen in figure 5.4 below, a successful developer model will support the preconditions until financial close. Historically, those were addressed by either an experienced utility (such as EDF in France in the 1970s–1980s), or an integrated nuclear technology vendor (Westinghouse between 1960s–1990s) in coordination with their national government.

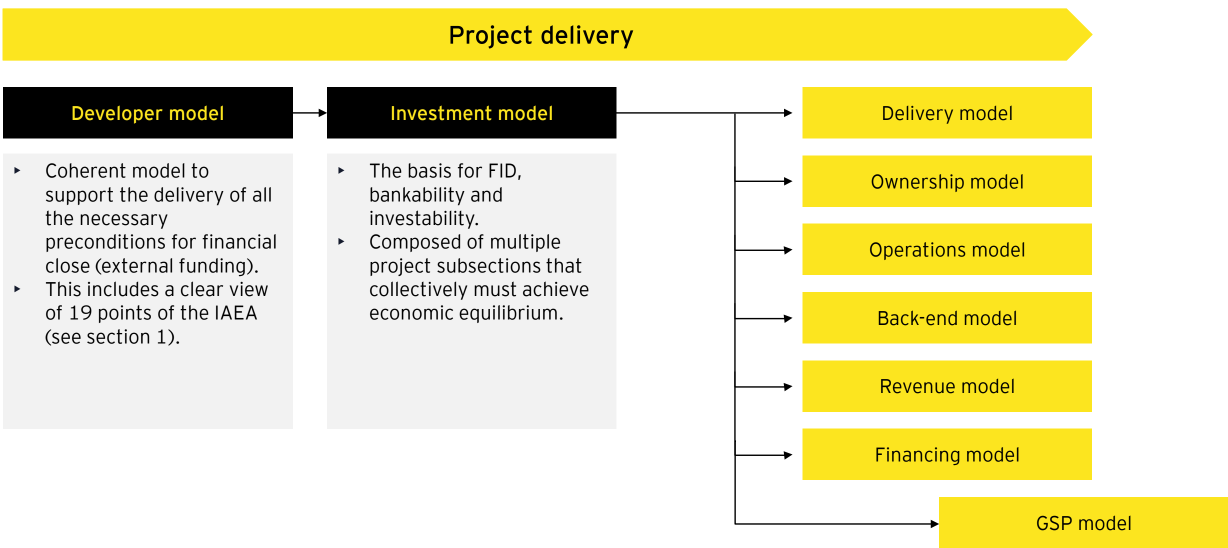


Figure 5.4: Project delivery components necessary to reach financial close

As interviewees indicated, few such structures currently exist with a clear nuclear newbuild experience as owners have not had many opportunities to take on that role, whilst vendors, offtakers and external financiers are typically unwilling to carry development risk. TVO in Finland is one of the few owners that have successfully led a nuclear energy project in Europe in recent years, but the unique conditions of the Olkiluoto 3 contracts and financing (in particular with respect to outturn delivery and completion cost performance) may actually be evidence of the exception, rather than the rule.

The advent of new nuclear designs SMR or AMR, on new sites and with new project constituents implies that successful, broad-based nuclear development in Sweden may need to follow a different model from the historic, vertically integrated utility-led development model. The options for large reactors will also need an update from the historic programs of the 1970s and 1980s, as integrated utilities have been broken up, or divested their nuclear energy activities. Greater reliance on specialized nuclear technology vendors will require a good interface management by the developing entity of the numerous contracts that will cover the deployment of a nuclear power plant.

A lack of integrated development and project management is at the source of the many issues that have been identified in nuclear newbuild projects. For instance, design changes and adaptations midway through construction were identified to be financially damaging for projects in reaching on-time- and on-budget completion. Licensing of a nuclear power plant is also a long-lead item which varies from country to country in Europe as each authority carries out its independent assessment of the safety and operability of the plant benefit of increased exchange with what was achieved in similar projects abroad.

A last example is a continuous change in policy, with the procurement of a nuclear energy program being delayed for many years as bids are analyzed over many iterations without reaching a final decision. In the Czech Republic, the first tender for Temelin 3 and 4 was held in 2009 but was cancelled due to a change in policy in 2015. A new tender is currently underway, and vendor selection will be complete by this summer after either EDF or KHNP is chosen as preferred bidder for a package of 4 reactors at Dukovany and Temelin.[62] Overall, the project was noted to be currently delayed with up to 10 years due to inconsistency in political support over this period.

Interviewees shared that enabling a successful development phase, all the way to FID, is a complex task. Having an entity with a clear role and responsibility to coordinate an efficient allocation of tasks and resources during the pre-development and development phases could prove critical to making the program bankable.

In recent years, nuclear energy development activities and skills have not been defined or resourced in a systematic way to deliver successful programs or projects in most "recomer" markets, including Sweden. A developer model (whether explicit or implicit) would set out the activities and resources required to deliver projects in the most holistic way possible, if the developer (organization, consortium, or informal grouping) is fully incentivized to set out the targets, enablers and assumptions and to define the assignments of all role holders across the program.

The EY organization noted that nuclear energy, being a long-term industrial policy goal, would need to have clarity all the way down to the policy instrument level, so that all participants can mobilise their resources at the appropriate time to reach their respective readiness levels at each project phase. Thus, a predefined developer model was floated as a potential answer to the various necessary preconditions to reach FID and the beginning of construction works.

Multiple potential models could exist, either relying on the government (state-led developer) to support the project by addressing program- and project-level issues, or a utility-led model where an existing, experienced and deeply-resourced owner-operator takes the lead in designing the overarching nuclear infrastructure program.

The first model is currently employed by the Czech Republic and Poland, where either an existing utility ČEZ Group or a recently formed developer Polskie Elektrownie Jadrowe (PEJ) are assigned to focus the attention of decision-makers on the roadblocks to completion. Such a model assumes

62 EDF and KHNP in running for expanded Czech nuclear tender, World nuclear news, February 1 2024

government-level mobilization with dedicated teams and working groups across ministerial agencies. Here, the state benefits from providing a strategic clarity by coordinating all the stakeholders towards a common goal.

The second model has been applied in Finland with the Mankala approach where a consortium of utilities funded and managed the project from beginning to end. Such an organization requires significant involvement from existing owner operators, and the participation of a great number of willing offtakers. In this model financial markets can be tapped at the corporate and project level to provide funding, thanks to the financial market depth of Sweden, the Nordics and Europe.[63]

Reflecting the interview process, multiple options could apply to this latter model:

- Owner-operator's lead, for example by companies such as Fortum, Vattenfall and Uniper Sweden
- End users' lead, with major players in energy-intensive industries that could play a willing offtaker and (potentially) investor role and
- Vendor's-lead, perhaps most applicable to FOAK SMR projects or other projects featuring "binary" risks and unknowns, such as licensability, deliverability, operability and unit performance or operations.

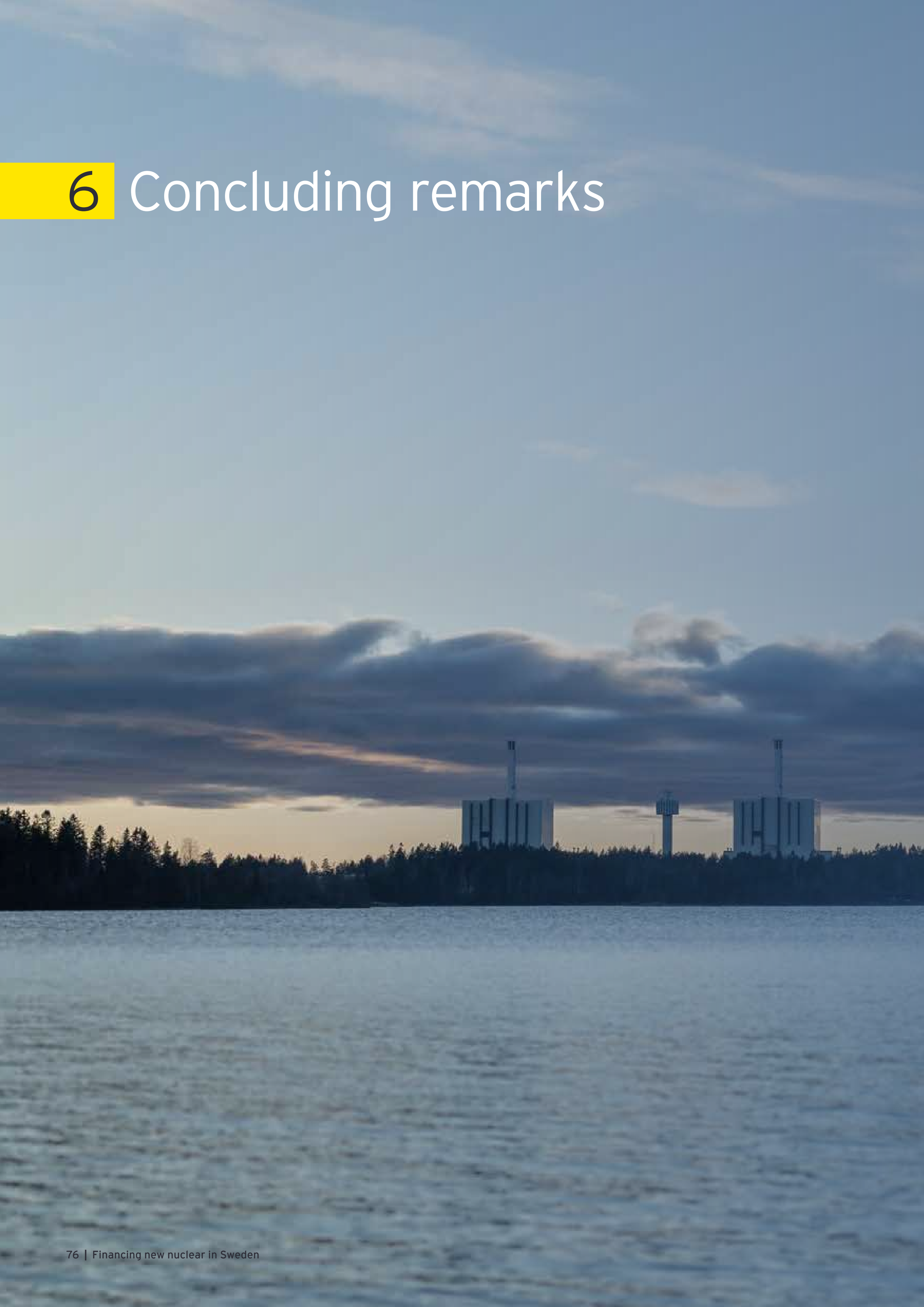
Interviewees emphasised the role of the Swedish government in undertaking NEPIO-like activities at the program level (including GSP definition), in order to allow the private sector to lead a successful development process for each project.

Key takeaways on definition of a new Swedish developer model:

- Interviewees communicated that, as with any energy technology, investors and lenders will assess the Swedish nuclear newbuild program through the lens of a detailed information memorandum that will reflect, ultimately, the investment proposition (or investment model).
- Interviewees recognized that nuclear investment models differ from country to country across the EU and other liberalised markets, and accordingly Sweden has the dual challenge and opportunity of formulating an investment framework that best suits its economic and political requirements.
- The future Swedish nuclear investment model could benefit from, and achieve acceleration thanks to, numerous pre-existing components and assets (operators, end users, regulatory capacities, sites, public acceptance, etc.).
- To cater for the broad choices available in terms of vendor partners, sites, offtakers etc., GSP design should ideally be incentivized and modular across five types of government support, reflecting where the EU or OECD competitive markets have faced gaps as in equity, debt, revenue, risk allocation and investment insurance.
- It was recognized in interviews that the nature of nuclear energy development requires significant time and resource to reach FID. Significant development resource is required to mature the specifications for investability at both the program and project levels. It is hard for the market to organise itself to deliver investable nuclear projects, so government incentives are required in the development phase (and possibly after, into construction, operations and decommissioning).
- A developer model was indicated to be helpful in providing an incentivized framework for nuclear energy developers to bring proposals forward, and to provide a feedback loop to government with respect to the various gaps that the market participants believe they are likely to encounter. These findings and gaps would be measured, and then mitigated in the parallel design of the GSP that would be implemented at FID.

63 How Sweden's stock market became the envy of Europe, Nikou Asgari, April 18 2024, news article Financial Times

6 Concluding remarks



Thanks to the strong support of Swedish Enterprise and its multiple members and organizations who participated in the interviews and early socialization of the report, the EY organization's interview process has been greatly enhanced. Coupled with market research and the team's unique experience with nuclear development and finance, this has generated private-sector data intended to support the Swedish government's decision-making for the next phase of its nuclear redeployment policy. Interviews were conducted with senior practitioners with the intention to inform future policymakers what may be required to deliver sufficient information to commercial lenders and investors.

The investment model templates that have emerged for nuclear newbuild across many countries feature specific roles for the government and state across a limited range of functions (being, any combination of equity, debt, revenue and risk allocation). Historically, no country investment model featuring third party (market) finance has been meaningfully replicated in another country. The most appropriate nuclear newbuild model for Sweden in 2024 cannot reasonably be advised or recommended without prior active engagement between the government and the market to this effect. Due to the potential wide range of equally desirable, innovative outcomes (technologically, commercially, industrially, financially, economically, etc.), the Swedish development process may require a sponsor organization with a sufficient mandate, and incentives for market participants to engage to deliver financially sustainable projects.

The concept of development model introduced in previous section refers to the framework and process by which competitive nuclear newbuild projects can be brought forward. Due to the specific nature of nuclear projects, featuring long lead times in multiple technical and non-technical areas, requiring strong coordination and cooperation between public authorities and private parties, nuclear development can be defined as the period from project proof-of-concept to FID.

The development timeframe historically covers five to seven years for nuclear projects with highly mature technologies in expansion markets (as opposed to newcomer markets), including first-in-a-while markets like Sweden. The preconstruction phase can last longer due to the iterative nature of nuclear energy development that must solve for multiple FOAK or first-in-a-while factors such as siting, public acceptance, environmental approval, nuclear regulatory capacity and approvals, supply chain resources and mobilization, owner-operator resources, physical security, safeguards, radioactive waste management, etc. In giving guidance to its member states, the IAEA Milestone Approach refers to 19 distinct "issues" that must be concurrently managed and solved for to achieve FID, being the point of project financial irreversibility.

6.1 Major risks to the Swedish model

A Swedish model should be developed based on lessons learnt from the analysis of precedent case studies of nuclear power plants and related government support packages. The interviews performed in preparation for this report provided valuable insights into the unique history, position and ambitions of the Swedish market players. Interviewees have expressed a certain number of asks which would need to be addressed by the government in the near term. These market views have been summarised below.

Development risk	▸ Based on interviews, there are significant market resources available to help lead and deliver a nuclear newbuild program in Sweden, but not to underwrite one. ▸ A government-orchestrated, incentivized developer model is advisable to bring together the various constituents of a successful nuclear program, therefore identifying capacities and bounding conditions, and by extension, the gaps where public resources may need to be mobilised.
Financing risks	▸ Market participants suggested that private financing for the first-in-a-while unit(s) without a relatively broad form of government support would be difficult (referring not just to credit guarantees, but potentially investor support, revenue support and development or delivery support, especially for the first-of-a-series project). ▸ Current plans are limited in definition, with credit guarantees to be provided but no definition of the overall finance plan.
Market risks	▸ Revenue model dependencies and influence of the electricity generation mix in Nord Pool and the European markets. ▸ Revenue certainty provided via the financing model and/or government guarantees. Private financiers indicated that revenue guarantees are critical for private financing.
Policy, regulation and political risk	▸ Market parties expect the government to provide some certainty in relation to political risk. This may involve guarantees or additional agreements for financial compensation in the event of early termination, as well as clarity on the future energy mix and role of nuclear.
Construction and completion risk	▸ Market parties see a role for the government during the construction phase due to the significant risks associated. Suggested options include providing returns through the remuneration model, providing financing (e.g., through a loan), state participation as shareholder and/or or liquidity provider). ▸ A distinction was made between "construction risk" (which the market can largely accept) and "completion funding risk" (which the market cannot accept for a first-in-a-series project) ▸ Provided there is a revenue guarantee, private financiers indicate a willingness to bear "ordinary" construction risks to the extent they can control them, suggesting that the initial Swedish nuclear projects may require more support than existing revenue protection and credit guarantee instruments provide.
Licensing risk	▸ Market parties indicated they are only willing to accept licensing and permit risks to a limited extent and expect the government to play an economically enabling role. ▸ Suggested options include the government providing financing or guarantees until the most critical permits become irrevocable, covering part of the additional costs in case of material changes in permit requirements. Government should also assess to allow for agreements to preallocate the impact of future changes in permit and nuclear licensing requirements. Other suggestions include early-stage concept testing and ensuring certainty on conditions and requirements from SSM. ▸ Private financiers suggest that government should bear the risk of higher costs, longer lead times and reduced unit performance resulting from unforeseen changes to licensing requirements, since this is by definition out of their control.
Back-end risk	▸ Private financiers are willing to fund decommissioning but relayed concerns with the natural tension between industry and government desire for innovation in the back-end and financiers' desire for continuity and avoidance of changes that impose shifts in risk and reward profiles across financial classes and timelines. ▸ Private financiers have shown little appetite for political interference leading to additional decommissioning costs. ▸ Current decommissioning and repository system is owned by the current operators with no guarantees of an extended scope. Here there is a potential role for the government to engage in ensuring the availability of a future solution.

In turn, the government could consider issuing guarantees to private financiers in one or more areas listed above as part of the risk mitigation effort of the Swedish model. Guarantees covering e.g., substantial cost increase and licensing during construction, decommissioning costs in the event of premature bankruptcy of the operator and to cover black swan events (e.g., incidents) should be considered depending on the overall risk from the chosen investment framework.

6.2 Identifiable gaps in the Swedish investment model

Looking at other international investment models applied to nuclear energy development, various options appear available to Sweden. As can be seen in figure 6.1, financial close can be supported by strong government intervention or by market participants (any combination of investors, vendors, offtakers and lenders), with sufficient interest and capabilities to take significant aggregated project development, delivery, operations and decommissioning risk.

Figure 6.1: Risk sharing between government and market in recent nuclear newbuild projects

On the government-led financial underwriting side of the spectrum, the programs have relied on the state providing a significant level of financial incentive and risk sharing. Figure 6.1 provides an overview of some of the latest large-scale nuclear power plant projects, where for instance in the Czech Republic and Hungary, a state-backed utility oversees the project, with either an almost complete financial underwriting from the host government on debt and equity (at Dukovany 5, though this project has not reached financial close). Equally, in this scenario, the host government can mobilise tied or commercial debt support through ECAs and government-to-government financing.

On the opposite end of the spectrum, the Olkiluoto 3 in Finland (Mankala model) and Flamanville 3 in France (Exeltium model) did not require specific government financial assistance (such as budgetary allocations, inter-governmental agreements and direct revenue support or off-take subsidies). Instead, a balance of risk and reward was agreed between the major project participants, namely the vendor, owner or operator and offtakers such that bankability could be assured, and the cost of capital reduced to competitive levels in the market.

Both transactions benefitted from owners (EDF and TVO) having sufficient balance sheets and multiple existing assets in operation, which helped enhance overall project bankability. Even though replicating these conditions has been unsuccessfully attempted in other geographies (Romania, US and Finland), it could nonetheless represent one viable option for Sweden in 2024 with sufficient funding.

	Hinkley Point C (UK)	Sizewell C (UK)	PAKS II (HUN)	Dukovany 5 (CZ)	Flamanville 3 (FRA)	Olkiluoto 3 (FIN)	Borssele (NL)	Lubiatowo-Kopalino (PL)	Sweden
Developer	EDF+CGN	EDF+UK government	Rosatom	EDF or KHNP	EDF	TVO	N/A	Westinghouse	TBD
Owner	EDF+CGN	EDF+UK government	MVM	CEZ	EDF	TVO	N/A	PEJ	TBD
Operator	EDF	EDF	MVM	N/A	EDF	TVO	N/A	N/A	TBD
Revenue mechanism	CfD	RAB	Merchant tariff	CfD	Exeltium	Mankala	N/A	Liekly CfD	TBD
Finance plan	Owner / Vendor balance sheet financing	RAB-based with owner / government-backed equity	Host government-backed with vendor-led inter-governmental agreement	Government-backed equity and debt	Owner balance sheet for base funding and SPV non-recourse financing for completion funding	Generator / offtaker cooperative structure (Mankala)	N/A	N/A	TBD
Funded Decom. plan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	TBD
Delivery model	100% owner / vendor risk	Shared risk through RAB	100% vendor risk	N/A	100% owner / vendor risk	100% vendor risk	N/A	N/A	TBD

Table 6.1: Comparison of investment models in recent nuclear newbuild projects

Sweden has still to detail what its requirements or implementation plan to meet the nuclear newbuild ambitions will be, but based on feedback from interviewees, the policy objectives could reasonably contain the following:

- Market finance needs to be tapped to the maximum extent possible and
- Price and competitiveness of the electricity produced needs to be optimized, while
- Preserving the investment capabilities of existing owners or operators in Sweden.

Understandably at this early stage, and unlike the more advanced nuclear power plant projects detailed in the table above, the Swedish government would benefit from consultations on how to approach each of the six categories of the investment model, particularly:

- Which company will provide the development initiative?
- Who will be the owner of the new plants?
- What revenue and financing mechanisms will be provided?
- Who will operate the new plants?
- How to finance back-end costs and risks (long-term fuel storage, treatment and disposal facilities, LTO and/or decommissioning, etc.)?
- How will the final risk allocation and delivery model be shaped?

These asks are key to handle efficiently and preferably in a near future. During the interview process, vendors and owners expressed concerns when looking at the proposed timeline shown in figure 6.2. Traditionally, nuclear technology procurement processes follow a multi-year process where:

- The first one to two years are dedicated to defining government policy and ensuring a long-term policy is put in place.
- The following three to four years are usually allocated to developing, derisking the project and reaching the FC or FID. This includes:
  - Technical feasibility and market consultations with potential vendors
  - The preparation of a bid invitation specification (BIS) process
  - A phase of joint bid development and modification with the bidders
  - A bid evaluation period (between six to 12 months) which leads to a preferred bidder selection
  - An early works agreement which firms up the technical definition of the project and the delivery model
- The last seven to eight years are expected to be a minimum for the construction phase.

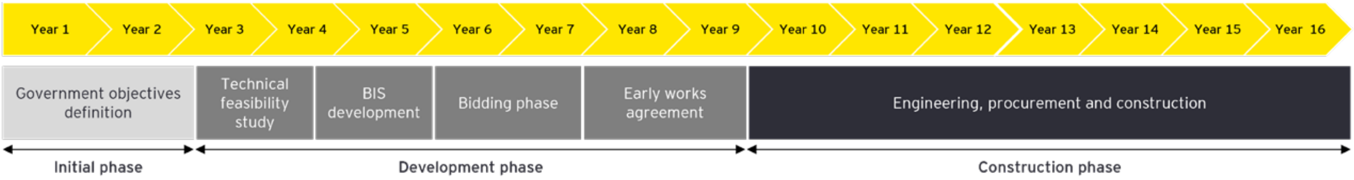


Figure 6.2: Schematic nuclear newbuild development and construction process

Working backwards from these assumptions, keeping in mind that Sweden is a first-in-a-while country, the government and market players in Sweden have already launched the procurement process to have the first nuclear power plant with the equivalent of two large reactors targeted by 2035. Indeed, the Czech Republic is currently in the middle of the new nuclear vendor selection (with a final decision to be taken by the summer of 2024) for the Dukovany and Temelin process for a first reactor to be put online by 2035 as well. However, the project definition has been ongoing for about 10 years in the Czech Republic, while Sweden has started in 2022–2023 to follow the same path.

For the Swedish government to meet the announced ambition of enabling the equivalent of two large reactors by 2035 would imply continued acceleration while ensuring the necessary development as bypassing key steps may result in further delays at later stage of construction.

During the interviews Sweden was encouraged to find ways to shorten the anticipated timeline without compromising on nuclear safety or viability of the investment model, though interviewees recognized that there are only limited options to do so. For example, one path of least resistance could be to commit to a bilateral vendor selection process, which could significantly reduce the duration of the development phase and enable a joint development plan with the selected vendor early on. However, such an option would bypass the traditional public tendering process. One example of this was Poland, which in its selection of Westinghouse made a commitment which moved its objectives forward in a decisive manner but was nonetheless controversial. Also, any such decision would need to be made concidering EC state aid rules.

Launching the process itself is the first step in the process. Thus, it is important for Sweden to explore the conditions at which financial markets and industry can support the project. In doing so, Sweden is encouraged to create a template GSP to identify how to optimize its support, using the five pillars previous introduced:

- Equity contributions or owner financial support
- Lender support
- Revenue support
- Project risk allocation
- Investor insurance

For instance, the pentagon in figure 5.3 represents the level of support provided in case of a large financial package with:

- Significant equity contribution from the government
- Full or majority underwriting by the government of project debt
- A long-term revenue mechanism (such as a CfD, or a RAB)
- A financial risk transfer mechanism for major risks such as project cost overruns and delays
- Indemnity clause against changes in policy

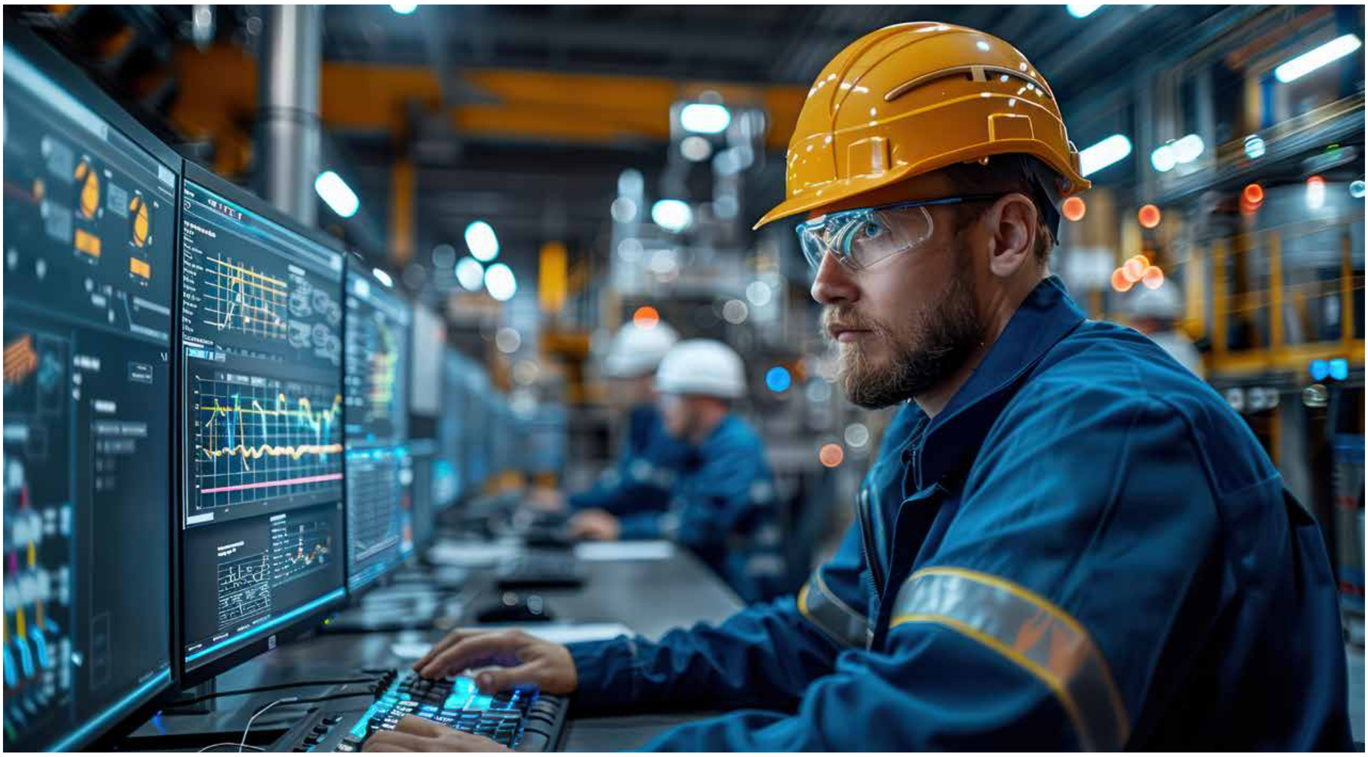
This package would be reflective of a high government contribution. The shaded areas in figure 5.3 indicate a possible share of the undertaking covered by the government, while the non-shaded area indicates the outstanding risks and costs that need to be borne by market players.

The proposed credit guarantees stated by the Swedish government offer only lender support, which is less than what other governments in Europe have deemed as necessary minimum package in previous instances. The Swedish government can communicate with the relevant players for each of those five pillars to identify what its final investment strategy will be.

> Credit guarantees cover financing and credit risk, not market and project risks, which are more significant and not yet well understood.
>
> **Financial institutions Interviewee**

> First loss support financing or guarantees would be a significant help, in addition to a risk transfer mechanism to the state for market and project risks.
>
> **Financial institutions interviewee**

Sweden is widely considered to be better positioned as a first-in-a-while country than most of the previous newcomer countries to leverage its nuclear industry. As such, Sweden can draw upon the existing owners and operators to support the program development and give way to a market-based procurement process. Even so, a clear risk-sharing strategy needs to be put forward for the program or project to be successful. The overall financial goal of the Swedish government could be to design a risk allocation model that enhances overall project bankability by limiting the exposure of the nuclear newbuild developers to critical project risks. In figure 6.3, key project risks are shown to be born primarily by the future plant owners and delivery partners.



Phase	Risk	Considerations	Owner	Delivery partners	Lenders	Govt
Construction	Interface risk	Swedish government will likely have to appoint a 3rd party professional firm to provide a full underwriting to the extent a Tier 1 delivery partner does not provide a full wrap.	High	Medium	Low	Low
Construction	Delay risk	Swedish government will likely have to provide a guarantee above a threshold.	High	Medium	Low	Medium
Construction	Cost overrun risk	Swedish government will likely have to provide a guarantee above a threshold.	High	Medium	Low	Medium
Construction	Technology risk	Swedish government will likely not have to provide an undertaking - however delivery partners must provide a strong narrative.	High	Medium	Low	Low
Construction	Permitting risk	Swedish government will likely have to provide an undertaking.	High	Medium	Low	Low
Operations	Fuel supply risk	Lenders can get comfortable with adequate due diligence.	Medium	Medium	Low	Medium
Operations	Nuclear liability risk	Above insurance pool limits, Swedish government will likely have to provide a partial undertaking.	Medium	Low	Low	High
Operations	Litigation or headline risk	Swedish government will likely have to provide a partial guarantee related to third party nuclear liability but not regular plant operations or performance.	High	Medium	Low	Medium
Operations	Operations risk	Swedish government will likely not have to provide an undertaking other than for Change in Law and/or Regulatory Baseline and/or Force Majeure.	High	Low	Low	Low
Operations	Revenue risk	Establishment of a mechanism to estimate with high reliability the price of electricity over the life of the plant is a key factor in ensuring bankability.	Low	Low	Low	Low
Others	Decommissioning risk	Swedish government will likely have to provide guarantees due to complex dismantling procedures carry a significant cost in the long term with an unpredictable valuation at project beginning.	Low	Low	Low	Low
Others	Safety risk	Control of civil nuclear safety and radiation protection to protect people and the environment.	Medium	Medium	Low	Medium

Highest risk exposure (Owner, Delivery partners)

- Minimizing the cost of risk (i.e. cost of financing) for the NPP owner and the delivery partners will ensure optimal LCOE and limit overruns and delay financing needs.
- Certain risks can be efficiently dealt with through state intervention, such as permitting, fuel supply, nuclear liability, safety, licensing and decommissioning funding.

Figure 6.3: Risk sharing overview during the lifetime of a nuclear power plant project

The most critical risks are generally located in the construction phase and can hardly be directly removed without financial guarantees provided by the Swedish government, as the matrix suggests. Nonetheless, Sweden can leverage the private sector to minimize its share in financing the undertaking by targeting the risks that are most critical to players of the supply chain.

6.3 Indicative terms of reference for the Swedish developer model

Many interviewees believe it is important that both the Swedish government and the involved market players work urgently on the investment model and developer model to agree on a risk sharing and derisking approach to enable nuclear newbuild projects in line with the stated ambition. Any approach where a single market actor tries to tackle these issues would likely have limited success due to the complex nature of the nuclear newbuild process.

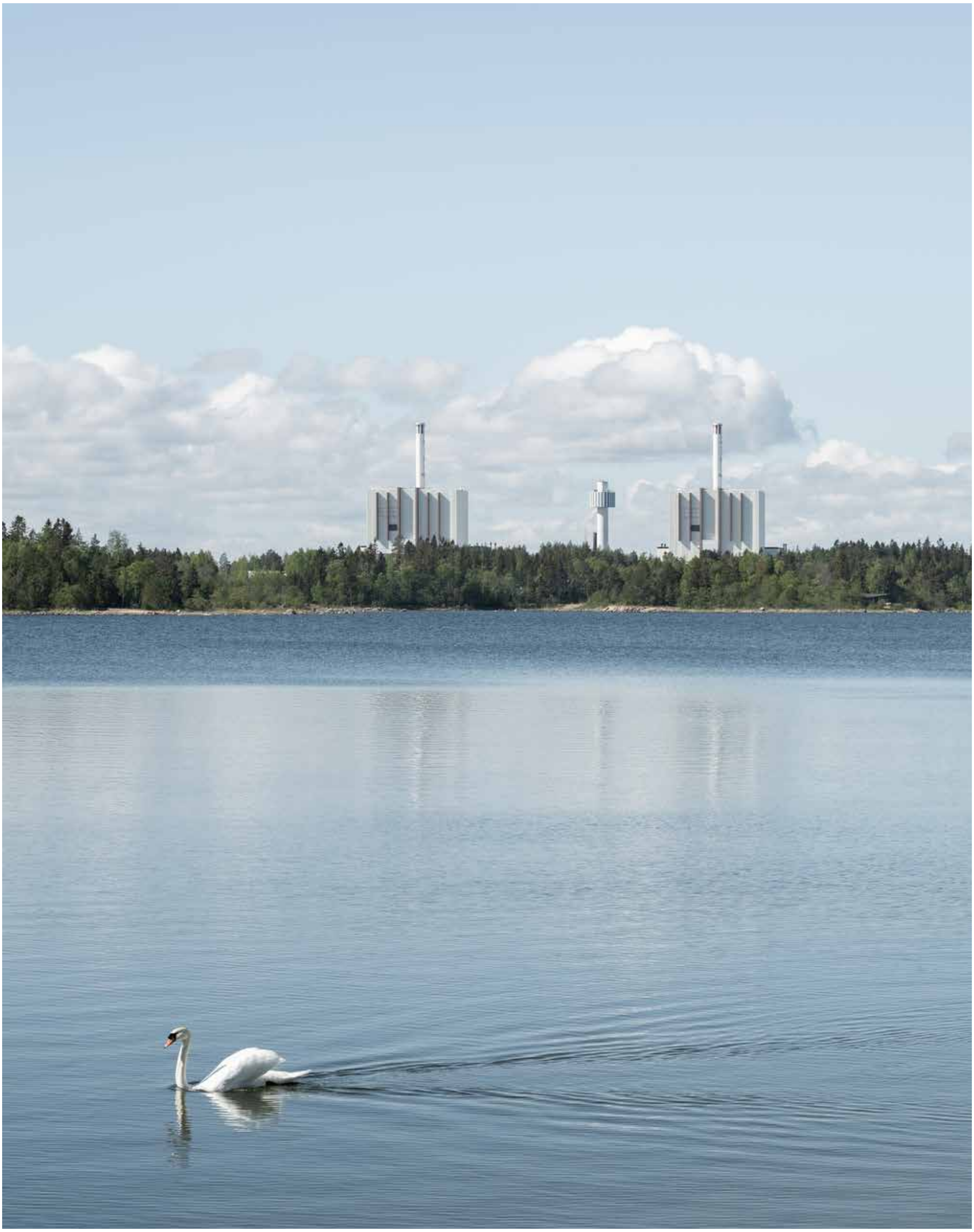
The following aspects are considered necessary for Swedish government nuclear energy development plans:

- Create an environment to negotiate with the various nuclear "constituencies," such as vendors, existing owners or operators, shareholders or investors, lenders, offtakers, regulators, grid company, supply chain and government offices in order to provide a clear roadmap and repartition of project risks.
- Provide a clear timeline of the future development activities and their architecture which could follow the below (illustratively as follows):
  - Roadmap of the developer group early, stating the division of benefits, costs, risks, timeline, resources and key performance indicators (KPIs).
  - Ways of working
    - Working groups (WG) covering technology, licensing, operations, siting, off-take, industrial supply chain, human capacity, legislative, contracting and financing
    - WG leaders to develop and adopt WG workplans
    - Developer leadership to instruct and commission an integrated workplan across WGs
  - Governance
    - Applications for membership or participation
    - Government appointee(s) moderate and/or act as rapporteurs
    - Reporting (both public and non-public)
    - Project level (vertical)
    - Transversal (horizontal)
    - Resources
  - Identify the relevant nuclear supply chain resources, costs and potential commitments.

The government would benefit from defining in greater detail how it will provide support to the developer group(s) based on the above listed negotiations.

To further illustrate potential actions for the Swedish government, based on the consultations with industrial parties and in comparison with similar FOAK and first-in-a-while countries, the following suggestions were made to the EY organization:

- Government could launch an eligible nuclear developer (END) auction whereby selected developers or consortia would receive support in the form of a developer assistance package (DAP) to develop their nuclear power plant project and achieve FC or FID.
- DAP would be developed by the government and authorised in Parliament, consisting of a combination of front-end resources to be made available to specific workstreams such as pre-qualified sites, points of connection, regulatory capacity, environmental authority capacity, including incentivized financing (whether grants or cost-share, equity, or debt).



These activities could be organised in a set of milestones that will be critical to achieve for the Swedish nuclear ambitions to become a reality:

	Milestones	Indicative timeline
1	The government sets out qualification criteria for eligible nuclear developers, forming any combination of investor, technology vendor, offtaker, site-owner and lender.	Within the next three to six months to develop and launch
2	Eligible nuclear developers submit a development plan featuring eligible design(s) (based on reference plants), target capacities and dates, and a developer workplan or integrated schedule to final investment decision, complete with workplan assumptions, decision gates and expected costs for each. Suggested decision gates would be: ▸ Basic design approval ▸ Site-specific approval(s) ▸ Business plan or financial model ▸ Financial close Developer will respond to term sheet for design approval and submits term sheets to the government, inviting the government to support development with the provision of pre-defined levers in the business plan, as well as funding or grants for design approval and site-specific approvals.	Within the next three to six months to develop and launch
3	Set a target and government resources for first FID. This should include further details and scope of the anticipated program over the next 20 years.	Within the next six months
4	Define government resources or government support package parameters (main deliverable of the Developer grouping). ▸ Government resource kit at FID (generic nuclear project) ▸ Government resource kit at first-in-a-series COD or operations (as applicable) ▸ Government resource kit at next-of-a-kind COD or operations (as applicable)	Within the next six to 12 months
5	Identify the key sites which will host the future new nuclear power plants and begin the feasibility studies with the targeted vendors. This will also initiate the first technological choices and firm up the potential supply chain choices.	Within the next year
6	Begin the initial tendering specifications definition, by creating a BIS development process in accordance with the IAEA standards. That phase will incorporate an initial feedback loop with technology vendors.	Within the next two years
7	Develop a full BIS with relevant input data on the allocation of risks from the bidders, and supply chain identification and evaluation.	Within the next three to four years
8	Evaluate the various bidders' proposals with a clarification period, and an assessment of residual risk to be managed by the future plant owner and the government.	Within the next four to five years
9	Select the final technology vendor and signing of an early works agreement to firm up the delivery conditions of the technical and non-technical bid.	Within the next five to six years
10	Identify eligible nuclear developers that make progress toward achievement of FID and will develop their target business plan at financial close featuring any desired, optimized combination of government debt, equity, revenue support, project risk allocation and investor insurance.	Within the next five to six years

Appendix A

Abbreviations

Abbreviation	Meaning
AMR	Advanced modular reactor
AR	Advanced reactor
ASN	French Nuclear Safety Authority
BIS	Bid invitation specification
BWR	Boiling water reactor
Capex	Capital expenditures
CAPM	Capital asset pricing model
CBA	Cost-benefit analysis
CfD	Contract for differences
CFPP	Carbon-free power project
Clab	Central interim storage facility for spent nuclear fuel
COD	Commercial operation date
CSRD	Corporate Sustainability Reporting Directive
DAP	Developer assistance package
DoE	Department of Energy
EC	European Commission
ECA	Export credit agency
EDF	Électricité de France
Ei	Swedish Energy Markets Inspectorate
EIA	Energy Information Administration
END	Eligible nuclear developer
EPC	Engineering, procurement and construction
EPR	European pressurized reactor
ETI	Energy Technologies Institute
EU	European Union
FC	Financial close
FE&P	Fuel, engineering and projects
FEED	Front-end engineering and design
FID	Final investment decision
FOAK	First-of-a-kind
FTE	Full time employee
GDP	Gross domestic product
GID	Government investment decision
GSP	Government support package
HMG	His Majesty's Government
HPC	Hinkley Point C
IAEA	International Atomic Energy Agency
IEA	International Energy Agency

Abbreviation	Meaning
IGA	Inter-governmental agreement
KEPCO	Korea Electric Power Corporation
KPI	Key performance indicators
KSU	The Nuclear Training and Safety Centre
LCOE	Levelized cost of electricity
LTO	Long-term operation
MIT	Massachusetts Institute of Technology
MR	Modular reactor
MSB	Swedish Contingencies Agency
MVM	Magyar Villamos Művek
NEPIO	Nuclear energy programme implementing organization
NIDP	National Infrastructure Development Program
NOAK	Nth-of-a-Kind
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
OECD	Organization for Economic Cooperation and Development
OECD-NEA	Organization for Economic Co-operation and Development — Nuclear Energy Agency
OEM	Original equipment manufacturer
Opex	Operational expenditures
PEJ	Polskie Elektrownie Jadrowe
PPA	Power purchase agreement
PV	Photovoltaic
PWR	Pressurized water reactor
R&D	Research and development
RAB	Regulated asset base
RTE	French Transmission System Operator
SFR	Disposal facility for short-lived operational radioactive waste
SKB	Swedish Nuclear Fuel and Waste Management Company
SMR	Small modular reactor
SPV	Special project vehicle
SSM	Swedish Radiation Authority
Svk	Svenska kraftnät
TSO	Transmission system operator
TVO	Teollisuuden Voima Oyj
UAMPS	Utah Associated Muncipal Power Systems
Vägverket	The Swedish Transport Administration
WG	Working groups

Appendix B

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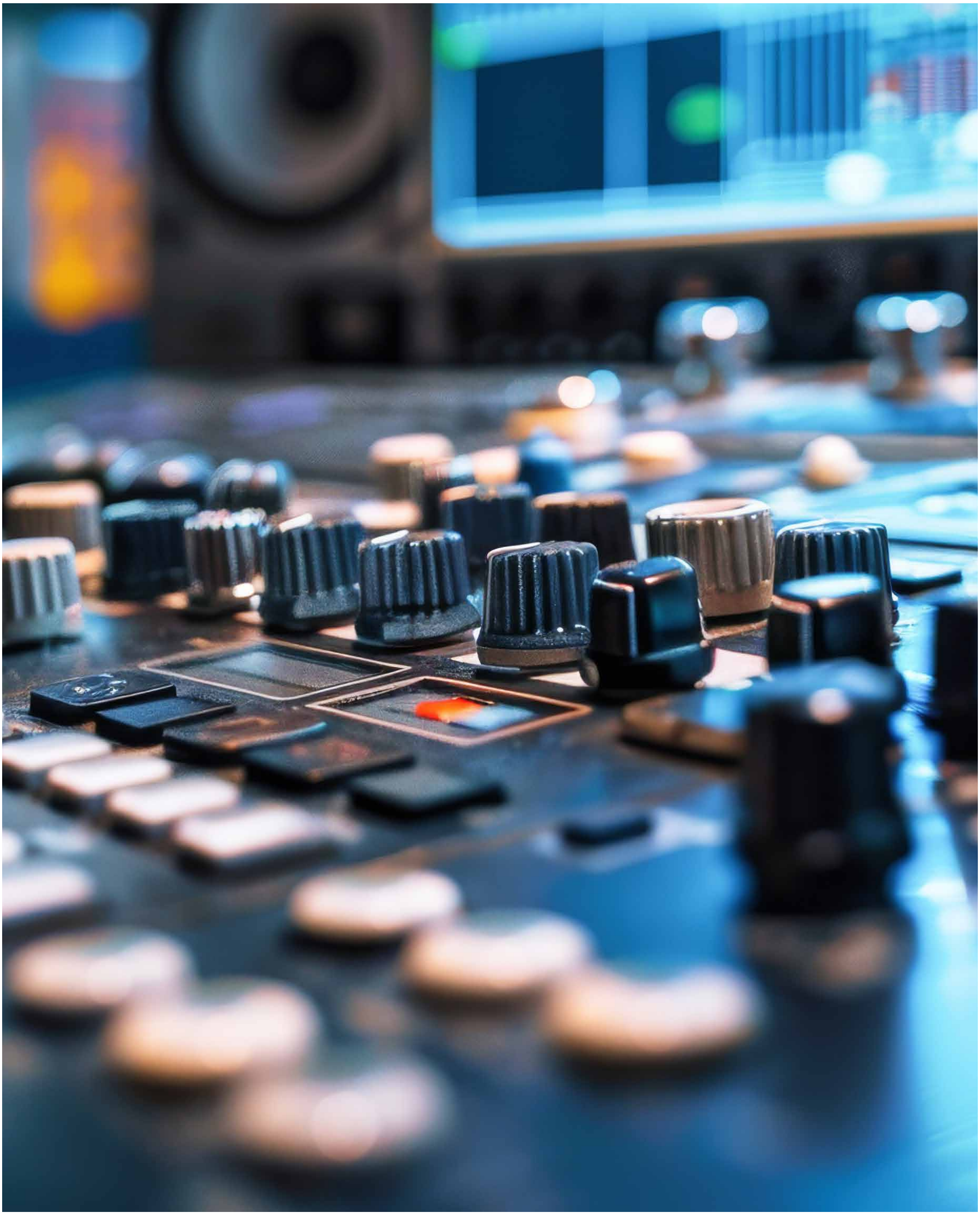

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