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Course of Managing the Energy Transition

Nuclear and the Sustainable Energy Mix: Evaluating the Reintroduction of Nuclear Power in Italy - The Newcleo Case

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Introduction

In recent years, the European debate on energy transition, which until the outbreak of the pandemic and the Russian-Ukrainian war had focused mainly on reducing emissions, has shifted its focus to the need to ensure both security of supply and industrial competitiveness. The latter issue, in particular, has catalysed public debate in the face of the crisis in European industry and its competitiveness vis-à-vis the rest of the world, triggered in part by high inflation due to energy prices. In this context, nuclear energy is no longer considered an alternative to renewable sources but is seen as a dispatchable component of a sustainable mix, capable of stabilising electricity systems, supporting hard-to-abate industrial processes, and reducing exposure to price volatility. The return of this issue to the Italian and European agenda, together with the emergence of Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs), has reopened questions of industrial policy, regulation and finance that require an integrated analysis at both the technical and political-legislative levels.

This thesis aims to answer a fundamental question: to what extent and under what conditions can new-generation nuclear power contribute to a sustainable energy mix for Italy, while at the same time being "bankable" for public and private investors? To answer this question, the thesis aims to go beyond a comparison limited to average production costs alone, analysing instead the interaction of three fundamental dimensions. The first is regulatory and institutional: the consistency of the national regulatory framework with EU law, the certainty and predictability of authorisation procedures, the role of an independent regulator and the effectiveness of cooperation between authorities and countries. The second dimension concerns finance: the identification of risk reduction mechanisms (*de-risking*) that are compatible with European sustainable finance and capable of reducing the cost of capital (WACC) throughout the entire life cycle of a project. The third dimension of assessment is at the industrial level: the serialisation capacity of SMRs/AMRs, integration into the national and European supply chain, and the potential to create multi-market outlets. The underlying assumption is that the effective contribution of nuclear energy to the national transition depends not so much on individual technical parameters as on the ability to orchestrate a virtuous interaction between procedural certainty and the adequacy of financial instruments. This combination, if properly implemented, should reduce implementation times and investment risks to the point of making a pipeline of projects viable and bankable by 2035 and scalable for the ambitions of 2050. To answer the research question, this thesis adopts a qualitative-analytical methodological design, based on the integration of academic literature, the analysis of institutional documents and an in-depth case study, thus seeking to construct a multidimensional interpretative framework. The reconstruction of the regulatory and financial context favours highly reliable primary and secondary sources, such as European Union acts and communications, recent technical reports, and reports from leading international agencies. This documentary basis is complemented by the empirical component, which is a qualifying element of this work. This component is based on a semi-structured interview conducted with two key figures from Newcleo responsible for institutional relations. The primary objective was to obtain an internal perspective on the company's strategic positioning, the Italian political and energy context, and the financing mechanisms that make an AMR project concretely "bankable". The information gathered is not confined to the case study chapter alone but is integrated throughout the thesis, particularly in the third and the concluding chapter, allowing the primary data to give substance to the analysis of the regulatory, financial and industrial context. The structure of this thesis follows an analytical path that moves from the general to the specific. The first chapter outlines the legal dualism between the Euratom Treaty and Article 194 of the TFEU, which has historically separated the technical dimension of nuclear safety from the Union's general energy policy. Then , the second chapter explores the divergent political-economic paradigms driving the global nuclear renaissance, from China's state planning to the market catalyst of the United States. The third chapter focuses on the "Italian case", highlighting its structural vulnerability as a price-taker in the European electricity market and the recent articulation of a new national strategy to reintroduce nuclear power into the energy mix. Building on these premises, the fourth chapter introduces the central thesis that the bankability of nuclear power is not an intrinsic market condition, but the result of a sophisticated architecture of contractual, financial and regulatory instruments. The fifth chapter represents the empirical core of the work, applying the theoretical architecture to the analysis of the Newcleo case study as a consistency test.

In the end, the sixth chapter shifts the analysis from a descriptive to a prescriptive dimension and, drawing on the information gathered from the interview, outlines a strategic roadmap for Italy, addressing the "bankability trilemma" and proposing a "dual-track" industrial policy for the future of advanced nuclear power in the country.

Chapter 1: Governing nuclear energy in Europe

1.1Regulatory dualism in EU energy law: Euratom and Article 194 TFEU

This chapter analyses the legal foundations of nuclear energy in Europe, a complex architecture whose cornerstone lies in regulatory dualism.

On the one hand, the Euratom Treaty of 1957 (European Union, 2016b), conceived alongside the Treaty of Rome, created an autonomous and highly specialised ecosystem for the civil use of nuclear energy. Its mission was to build a solid and predictable technical and administrative framework, focused on coordinating research (through the Euratom programme and the JRC), defining common safety standards (the Basic Safety Standards) (Council of the European Union, 2013), controlling fissile materials and strategically managing the fuel cycle, entrusted to the Euratom Supply Agency (European Union, 2016b, arts. 52–76). However, this very solidity, designed for maximum safety and stability, also reveals its inherent limitations. Forged in the 1950s, its original design is centred on safety, safeguards and control.

On the other hand, there is Article 194 of the TFEU (European Union, 2016a, art. 194), which frames energy in a more modern and systemic perspective. The result is an inherent tension: the priorities of the past struggle to fully integrate with today's challenges of climate neutrality, industrial competitiveness and energy security. This chapter explores how this dualism shapes the taxonomy of sustainable investments (European Parliament and Council, 2020; European Commission, 2022; JRC, 2021), the governance of the sector and financial instruments.

The moment when the "dual track" of European nuclear power finally crystallised was with the entry into force of the Treaty of Lisbon on 1 December 2009 (European Union, 2007). Instead of reforming or integrating the nuclear world into the nascent energy policy, the Treaty opted for coexistence: it introduced the new Article 194 of the TFEU, dedicated to energy, but left the Euratom Treaty intact, as if it were a legal universe unto itself.

This decision creates a profound divergence in terms of content, causing energy in Europe to travel on parallel tracks. On the one hand, Euratom remains a highly-specialised body, focused on the technical aspects of safety, safeguards and fuel cycle management. On the other hand, there is Article 194, which outlines the architecture of the common energy policy in a broader sense: the creation of an internal market, security of supply, energy efficiency, the development of renewables and the interconnection of networks are the new objectives on which it is based.

This separation translates into two different "speeds" of decision-making at the institutional level. While general energy policies based on Article 194 follow the co-decision procedure, placing the European Parliament at the centre of the process, decisions within the Euratom framework relegate the Parliament to a predominantly consultative role, leaving the final power in the hands of the

Council. On the one hand, this ensures continuity and technical consistency, but on the other, it risks introducing structural rigidity: the Euratom system, which is less permeable to political change, risks slowing down the integration of nuclear power into rapidly evolving climate and energy instruments. The whole issue rests on an even deeper political divergence. Article 194, while outlining the Union's energy policy, is silent on nuclear power. This, combined with the principle of subsidiarity, acts as a confirmation of national sovereignty: the choice of whether or not to include nuclear power in their energy mix, and how, thus remains an inviolable and undisputed prerogative of individual Member States. This divide between the two systems has a concrete and tangible impact on those who operate and invest in the nuclear sector. For operators and financiers, the stability of safety rules, guaranteed by Euratom, clashes with much more ambiguous market and political signals on the long-term role of nuclear power in the Union's strategies. The result is a climate of regulatory uncertainty that ultimately weighs on the cost of capital. Thus, the possibility of financing a new nuclear project remains strongly anchored to the individual national context, both in terms of authorisation procedures and public guarantees, creating a deeply heterogeneous landscape across European countries. The Fukushima disaster in 2011 acted as a catalyst. The European response focused almost entirely on further strengthening the already solid technical pillar. The Nuclear Safety Framework Directive was made even more stringent (Council of the European Union, 2009; Council of the European Union, 2014), imposing stricter requirements on the independence and capabilities of national authorities. At the same time, the drafting of national programmes for the management of spent fuel and radioactive waste (Council of the European Union, 2011) was made mandatory. Bodies such as ENSREG (European Nuclear Safety Regulators Group) also institutionalised regular peer review cycles and stress tests; dialogue with WENRA (Western European Nuclear Regulators Association) contributed to greater convergence of standards (European Commission, 2007; WENRA, 2020). All this has created an undoubtedly solid regulatory and practical standard, which reduces asymmetries and increases the reliability of the European system. However, its limitation remains: it is, by its very nature, confined to the technical and regulatory dimension alone, without bridging the gap with general energy policy.

On a political and programmatic level, a first ambitious attempt to bridge this gap came with the 2015 Communication on the Energy Union (European Commission, 2015). On this occasion, the European Commission outlined a unified plan based on security, market, efficiency, decarbonisation and innovation. However, even within this strategic vision, nuclear power continued to occupy not a position of prominence, but an ambiguous and marginal one. While formally recognising its status as a low-emission technology, its role was downgraded to a predominantly technical dossier, rather than being promoted as a cornerstone of European energy integration. On the one hand, this choice has

certainly proved diplomatically astute in defusing tensions with Member States opposed to nuclear power, favouring consensual issues such as renewables and efficiency; but, on the other hand, it has ended up crystallising the idea in European nations that the fate of nuclear power was a purely national issue. This has inevitably limited the development of common regulatory and financial instruments, sending an uncertain signal to the markets about its long-term bankability.
The distinct national trajectories of individual Member States reflect this dynamic. They range from France's sovereign and integrated supply chain to Germany's gradual but definitive phase-out, to be completed in 2023 (BMWK, 2023; BMUV, 2023); from Italy's confirmation of its exit, ratified by a referendum in 2011 (Italian Ministry of the Interior, 2011), to the constant fluctuations in Belgium and Sweden, torn between system security requirements and internal political pressures. The legal architecture of the Union has never definitively replaced sovereign choices on the energy mix. Nuclear power continues to depend critically on domestic consensus and specific institutional architectures, with immediate repercussions on implementation times, risk allocation and the contractual structures of each project, to the detriment of true European integration.

The resulting balance is therefore unstable: Euratom provides the technical basis, Article 194 enables the common energy policy, but the link between the two dimensions is not yet fully integrated.

1.2 Targets, numbers and the financial turn in EU energy policy

The foundational legal architecture of the European Union, which balances the supranational objectives of the Euratom and TFEU treaties with the principle of subsidiarity, has largely determined the path of the Green Deal and REPowerEU (European Union, 2016b; European Union, 2016a, art. 194; European Commission, 2019; European Commission, 2022). By leaving the final choice on the energy mix to Member States, this framework explains why, despite ambitious climate targets, nuclear energy has consistently been kept in a secondary position. To build consensus and ensure rapid policy implementation, Brussels strategically chose to anchor its energy architecture on the less divisive pillars of renewables and energy efficiency (European Commission, 2019; European Commission, 2022).

This strategic choice manifested in a series of ambitious targets: a net reduction in emissions of at least 55% by 2030 (European Union, 2021), a binding target of 42.5% for renewables in final energy consumption (with 45% as an indicative upper value) (European Parliament and Council, 2023a), and a further 11.7% reduction in energy consumption (European Parliament and Council, 2023b). These goals were supported by powerful financial instruments such as the Just Transition Fund, InvestEU, and the Modernisation Fund (European Union, 2021a; European Union, 2021b; European Commission, 2025). Despite the rhetoric of a "green industrial revolution", the implementation of this regulatory framework treated nuclear power more as a matter of technical compliance than as a strategic pillar of decarbonisation.

The 2021–2023 energy crisis served as a severe stress test for this strategy, exposing its underlying fragilities. With the REPowerEU plan, the Commission's emergency response focused on immediate, rapidly scalable measures: reducing dependence on Russian gas, diversifying supplies via LNG and alternative pipelines, and further accelerating the deployment of renewables (European Commission, 2022). While recognising the urgency of moving away from gas, the plan did not position nuclear energy as a central option for a short-term response. Consequently, the transition was managed mainly on the electricity front with variable renewable sources, supplemented by emergency demand-side measures. In several countries, this even led to the maintenance or reactivation of fossil fuel back-up capacity to ensure system security.

The economic consequences of this shock have been stark, with electricity prices for households and businesses reaching historic highs (Eurostat, 2025). As documented by institutions like Bruegel (2024) and in the Draghi Report (2024), this price volatility has damaged the competitiveness of energy-intensive industries and highlighted Europe's structural vulnerability. The analysis pointed to two main factors: a significant price and volatility gap compared to global competitors, and the fragmentation of European capital markets, which keeps capital costs high for transformative investments. This evidence revealed a clear need for an energy portfolio that combines the growth of renewables with a stable supply of dispatchable, low-carbon capacity, capable of stabilising prices and supporting long-term contracts.

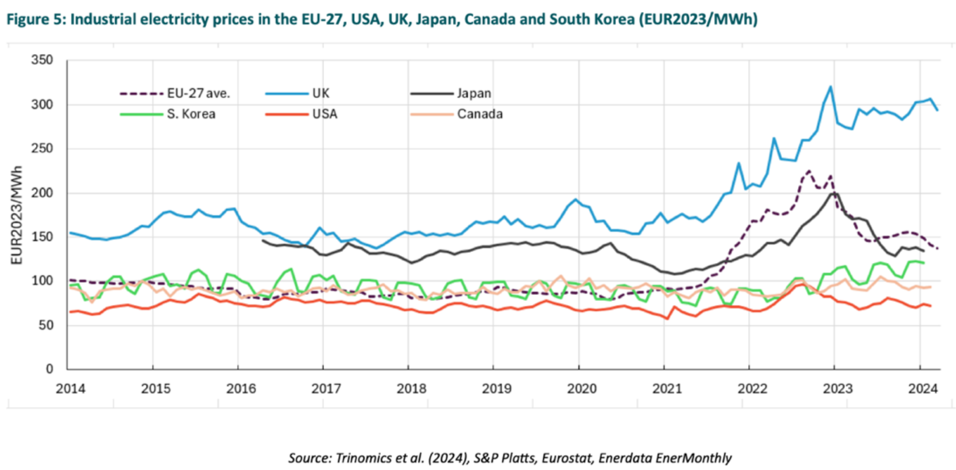


Figure 1 – Electricity prices for industry: the EU–US differential 2014–2024 (EUR2023/MWh). After the shock of 2021–2022, the gap remains wide, with the US at historically low levels (European Commission, 2025).

Seen through this lens, the original political calculation of the Green Deal and REPowerEU, while understandable for building rapid consensus, now appears insufficient to respond to the renewed geopolitical and economic conditions. Other major economies have taken a more direct route, explicitly integrating nuclear power into their decarbonisation strategies with robust policy and finance schemes designed to reduce construction risk and lower the cost of capital. The United States, for example, has implemented tax credits and programmes to preserve its existing fleet (US IRS, 2023; US DOE, 2025), while the United Kingdom has adopted the Regulated Asset Base (RAB) model for large-scale projects (UK Parliament, 2022; Ofgem/LCCC, 2025) and is pursuing Small Modular Reactor (SMR) projects through Great British Nuclear (GBN, 2024).

In Europe, the absence of a unified political position has meant that the attempt to fill the political vacuum has shifted to more indirect and technical arenas: the EU Taxonomy for sustainable activities and the design of financial instruments (European Parliament and Council, 2020; European Commission, 2022; JRC, 2021). It is here, in the transition from technical recognition to the complex issue of bankability, that the next chapter of European nuclear history is being written.

1.3 The EU taxonomy and the bankability gap

The European Union's primary instrument for navigating this transition from technical recognition to the ability to attract private capital is the Taxonomy, created with the ambitious goal of establishing a common language for sustainable finance across all countries, channelling capital towards investments aligned with the clean energy transition *(European Parliament and Council, 2020)*. Since its inception, however, nuclear energy has been the "litmus test" for these policies: it is true and proven that it meets the technical requirement of low carbon intensity, but politically it is characterised by a legacy of concerns related to safety and the management of the entire fuel cycle.

At the heart of the European debate has been the "do no significant harm" (DNSH) principle, which requires any sustainable activity not to compromise other environmental objectives, such as biodiversity or the circular economy (European Parliament and Council, 2020, Art. 17). The Joint Research Centre (JRC), on behalf of the Commission, analysed nuclear energy through this lens, concluding that, with adequate safety measures in place, its impacts are no greater than those of other technologies already included in the Taxonomy (JRC, 2021).

The inclusion of nuclear energy in the 2022 Complementary Delegated Act, albeit under very stringent conditions, immediately reignited the European political divide on the issue (European Commission, 2022a). The decision, supported by a bloc of pro-nuclear states, triggered the predictable backlash from opposing countries, whose motivations are rooted in established national strategies. Austria, with its strong historical internal opposition to nuclear power and supported by Luxembourg, challenged the act in court, accusing the Commission of greenwashing and violating the "do no significant harm" (DNSH) principle *(Euronews, 2022; European Union, 2023)*. Germany, while not participating in the appeal for reasons of political pragmatism, expressed firm opposition to defend the consistency of its nuclear phase-out (Atomausstieg), a pillar of its energy transition.

This divergence in reactions confirmed that the issue remains an unresolved political impasse. The decision to proceed with a delegated act allowed for a quick decision, but also highlighted the fragility of the consensus, bypassing an ordinary legislative debate that could have consolidated the democratic legitimacy of the choice.

On the financial front, the green light for the Taxonomy is a necessary but not sufficient condition. In principle and "on paper", classification as "green" allows investments to align with new transparency requirements for companies and financial intermediaries, such as the SFDR and CSRD (European Parliament and Council, 2019; European Parliament and Council, 2022). In practice, the Taxonomy's "green" label does not guarantee a project's bankability, but is only a starting point. In fact, a project's ability to attract private capital depends on a much more concrete ecosystem of trust, which is based primarily on three essential conditions. Firstly, capital markets need to be deep enough to mobilise the billions of euros required for the initial investment. Secondly, guarantee schemes, often publicly led, are essential to protect investors from the considerable risks of the long and complex construction phase. Finally, the political and regulatory stability of the country is crucial, ensuring a certain and predictable long-term horizon, sheltered from sudden changes in political and regulatory direction. Without these three conditions, technical recognition struggles to translate into market confidence and, consequently, into real investment.

This is the crucial issue also highlighted by the Draghi Report: without a more integrated Capital Markets Union and common technical and financial instruments to lower the cost of capital for capital-intensive projects, the de jure recognition of the Taxonomy struggles to translate into de facto confidence on the part of investors *(European Commission, 2024)*.

The Taxonomy has provided a scientific and legal basis for the conditional inclusion of nuclear power. On the other hand, the political divide between Member States and the choice of a "technical" regulatory vehicle keeps the uncertainty perceived by the market high. While other jurisdictions have resolved this ambiguity with explicit support instruments, such as tax credits or dedicated regulatory models, the debate in Europe is shifting from mere regulatory eligibility to the search for financial and industrial planning mechanisms that can make projects not only possible on paper, but also concretely financeable and achievable on a large scale.

1.4 How the energy crisis reshaped EU nuclear strategy through PINC 2025, the European Nuclear Alliance and the SMR Industrial Alliance

In order to make the energy transition a reality, overcoming political divisions and market uncertainties, the European Union has equipped itself with in-depth sector analysis tools. The main reference point for the nuclear sector at European level is the Programme Illustratif Nucléaire (PINC). This is not a binding law, but a fundamental technical document, provided for in Article 40 of the Euratom Treaty, which offers a strategic overview of the current and future state of the nuclear sector in the EU and, above all, quantifies industrial and investment needs.

Its importance lies precisely in its ability to shift the debate from an ideological to a quantitative level. Instead of debating "whether" nuclear power is appropriate, the PINC provides concrete data that serves as a basis for strategic planning and policy decisions, making the debate more pragmatic and focused on problem solving (European Commission, 2025a). The 2025 edition marks a clear change in vision, no longer framing nuclear power as a merely "tolerated" technology, but as a strategic lever for decarbonisation and competitiveness. The political message is that the transition must not only be driven by renewables, but also complemented by nuclear power, as the stability of the system cannot rely solely on gas as a flexible source in the medium term (European Commission, 2025a; Eurostat, 2025).

In quantitative terms, the PINC outlines an industrial ambition that sees net nuclear capacity increase from around 98 GWe to 109 GWe by 2050, with a wide range of uncertainty (from less than 70 GWe to over 140 GWe) reflecting the risk of actual implementation. Achieving this target depends on the success of life extension programmes (LTOs) and the timely construction of new units. To support this path, DG Energy estimates that investments of around €241 billion will be needed by 2050. These amounts do not replace, but complement, spending on renewables and networks, as the presence of programmable nuclear capacity reduces system costs and price volatility in an increasingly electrified economy (European Commission, 2025a).

To effectively implement this strategic vision and address the bottlenecks identified by the PINC, the Union has promoted a dual cooperation structure. The first is the European Nuclear Alliance (ENA), an intergovernmental political platform created to "normalise" nuclear power on the European agenda and create a common front on sensitive issues. Italy's accession in June 2025 strengthened its negotiating power in the Council (Élysée, 2024; Eunews, 2025; MLex, 2025). This political effort is complemented by the European Industrial Alliance on SMRs, whose yardstick is not political declarations but industrial deliverables. Its mission is purely operational: to accelerate the construction of the first modular reactors in Europe (*first-of-a-kind*) by the early 2030s.

To achieve this goal, the alliance is taking action on several concrete fronts: it maps and seeks to resolve bottlenecks in the supply chain, such as in the production of large forged components; it promotes the standardisation of components and processes as a fundamental requirement for mass production; it also supports the creation of a pipeline of candidate projects, helping to structure them in such a way as to make them genuinely bankable to investors. (European Commission, 2024a; NucNet, 2024).

This dual effort by the EU faces structural obstacles that both initiatives aim to overcome. The most critical challenge is that of licensing: to exploit the advantage of SMR modularity, the PINC and alliances are pushing for "enhanced cooperation between willing countries" to experiment with forms of mutual recognition between national safety authorities. Equally crucial is the geopolitical-industrial dimension: the ENA provides a basis and a political framewrok for diversifying away from Russia in the fuel cycle, while the SMR Alliance focuses on European supply and works downstream to qualify European suppliers and unlock the investments needed for serialisation, including those for advanced fuels such as HALEU (European Commission, 2023; Euratom Supply Agency, 2022; Euratom Supply Agency, 2025).

Finally, there remains the enabling condition without which these initiatives risk remaining theoretical: a financial and regulatory framework that makes revenues predictable and risks manageable. This is where the discussion converges on a "policy toolbox" that includes Contracts for Difference (CfDs), RAB models and public guarantees. The Draghi Report emphasises that without more developed capital markets and targeted de-risking instruments, the cost of capital in Europe will remain an insurmountable obstacle for large infrastructure projects (European Commission, 2024; European Commission, 2025a; European Commission, 2025b).

Thanks to the strategic vision of the PINC combined with the operational action of the two alliances, nuclear power has moved from the margins to the centre of European industrial policy. However, the measure of success will be operational and will be based on: a regulatory framework that enables a scalable SMR process, effective financial instruments to lower the WACC of pioneering projects, and a concrete strengthening of the European supply chain. If these three plans move forward together, ambitions can be translated into investment decisions and real capacity within the next decade.

To fully understand the scope and urgency of this new industrial and political architecture, it is necessary to analyze the crisis that acted as its catalyst. The structural vulnerabilities of the European energy market, brutally exposed between 2021 and 2023, provide the essential context for why the debate has shifted so decisively from principles to execution.

The energy crisis of 2021–2023 was, in essence, a gas price shock that the marginalist design of the European electricity market amplified and transmitted throughout the economy. The mechanism works as follows: in order to meet demand at any given hour, the price of electricity for all producers is set by the most expensive plant needed to satisfy consumption, which is very often a gas-fired power station. Thus, when in August 2022 the price of gas on the European reference market (TTF) exceeded €300/MWh (more than ten times the average of the previous decade), the impact on wholesale electricity prices was devastating and systemic. Emergency measures, while mitigating the shock, did not resolve the structural issue: how to reduce exposure to gas volatility at times when it "sets the price" of energy. (ACER, 2022; ECB, 2022; Council of the European Union, 2022).

The recent shock has had a strong and uneven impact on end consumers, with a transfer to bills which, although on average less than 50%, has brought prices to historically high levels, which persist even after the end of the acute phase of the crisis. At the same time, the growing penetration of renewables has given rise to an apparently paradoxical phenomenon: a drastic increase in the number of hours during which electricity prices become negative, signalling a surplus of variable generation that the grid is unable to absorb. This is not only a symptom of the lack of storage and demand flexibility, but also evidence of an unbalanced generation mix. As long as gas continues to set the marginal price for one-third of the hours in a year, as was the case in 2023, volatility and risk premiums will remain structurally high (Hernnäs et al., 2023; DG ENER, 2024; OECD, 2025; Eurostat, 2025).

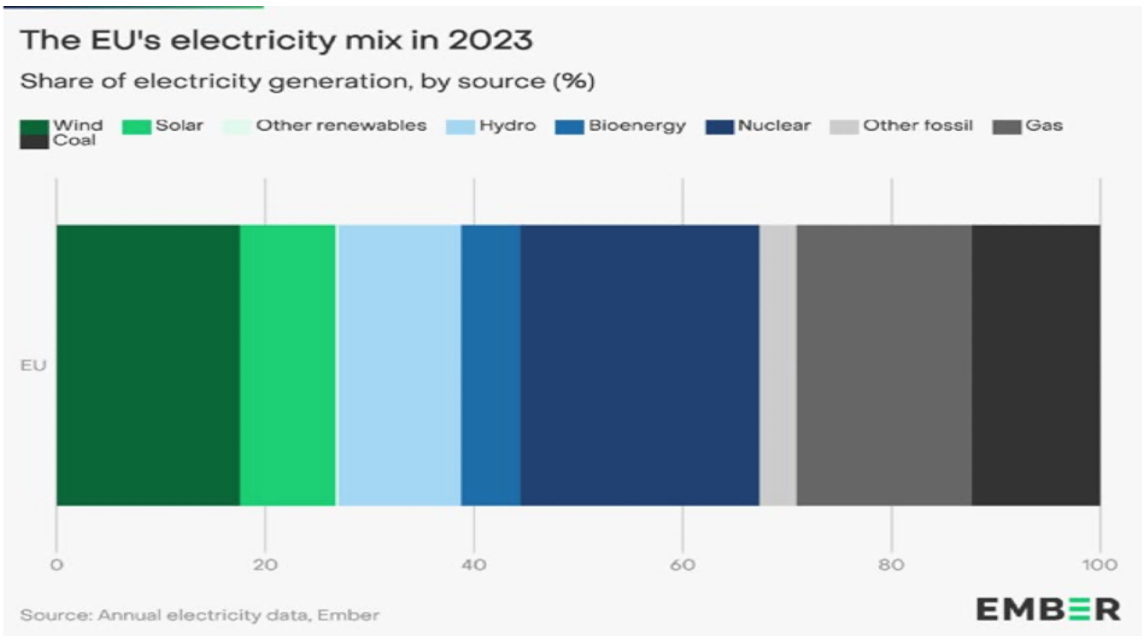


Figure 2 — EU electricity mix in 2023 by source (%). Nuclear is the single largest source (23%), while wind and solar combined account for ~27% and fossil fuels fall below one-third of generation. Source: Ember, European Electricity Review 2024, p. 79

Analysis of the crisis suggests moving beyond the debate focused exclusively on market design in favour of a strategic approach based on diversification of the energy portfolio. A system consistent with the 2040 targets must in fact combine the growth of renewables with a credible share of low-emission programmable capacity. In our investigation, the role of nuclear power is not to replace renewables; rather, it serves as a complement that performs two functions: it controls and limits the influence of gas as the marginal unit responsible for price determination and provides stability for long-term price expectations, compressing risk premiums in supply contracts. (European Commission, 2024; Bruegel, 2024).

This does not imply a focus on nuclear energy everywhere, but rather a rational assessment based on total system cost. Where renewable penetration is significant and exposure to gas remains critical and a base of firm, low-carbon power that reduces implicit volatility and the risk of sudden price spikes. Market design needs to be revised to reward these systemic benefits, but enabling technology remains crucial. Without low-carbon programmable capacity, the system remains inherently exposed to gas risk. The Draghi Report also highlights that, in the absence of diversified energy portfolios that reduce uncertainty, the cost of capital for the transition remains prohibitive, condemning Europe to a competitive disadvantage compared to jurisdictions that have already integrated stable, low-emission energy into their strategies (European Commission, 2024; Council of the EU, 2024; ENTSO-E, 2024).

Chapter 2: Global nuclear energy beyond the European Union

2.1 Electrification and the global map of nuclear growth

The global energy landscape is undergoing a profound transformation, with nuclear energy re-emerging as a key player. However, what we are witnessing is not a uniform renaissance, but a complex and multifaceted phenomenon, driven not only by the imperatives of decarbonisation, but also by a powerful convergence of geopolitical, technological and economic factors. The global debate on energy transition is now dominated by a twofold urgency: the need to accelerate decarbonisation in order to meet climate commitments and the imperative to ensure security and stability of supply in the face of exponentially growing electricity demand. Nuclear energy is re-emerging as a strategic element in the energy portfolio of many nations. This dynamic is redrawing the global energy map, highlighting a clear divergence in trajectories between the historical nuclear powers of the West, the new Asian superpowers and Russia's strategic assertiveness. This chapter aims to analyse this nuclear renaissance, going beyond a purely quantitative reading to offer a strategic interpretation of the different national agendas. The analysis will demonstrate how competition for global influence, security of supply and technological leadership have become drivers as powerful as, if not more powerful than, the energy transition itself.To understand the forces shaping the sector, it is necessary to move beyond a static view and adopt a dynamic approach. The International Energy Agency (IEA)'s World Energy Outlook 2024 outlines a scenario in which the electrification of end-use consumption, from transport to industrial processes to data centre power, drives global electricity demand to grow at twice the rate of overall energy demand (IEA, 2024). While the expansion of variable renewable energy sources (VRES) is proceeding at an unprecedented pace, the IEA stresses that their large-scale integration requires the support of programmable, low-emission technologies capable of providing continuous and reliable energy (IEA, 2024). In this context, analysis of global operational data confirms the crucial role played by the existing nuclear fleet. According to the World Nuclear Association's (WNA) World Nuclear Performance Report 2024, global nuclear production reached a record 2,667 TWh in 2024, surpassing the previous historical high (WNA, 2024).

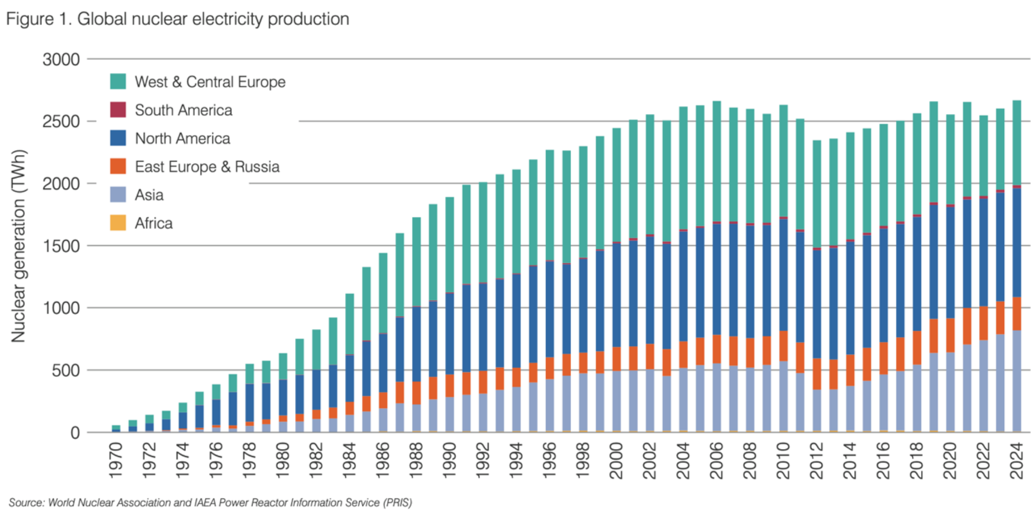


Figure 3— Global nuclear electricity production (1970–2024, TWh): 2024 marks a historic record: 2,667 TWh, with growth driven by Asia and the gradual return of the French fleet. Source: World Nuclear Association (2025), Fig. 1, p. 5.

This result was achieved with a global average capacity factor of 83%, a value that testifies to operational reliability superior to any other source of electricity generation and which has remained consistently above 80% for over two decades (WNA, 2024). This exceptional performance, coming from a fleet of reactors whose average age is increasing, reveals a fundamental dynamic: a significant part of nuclear power's current contribution to energy stability comes from maximising the value of existing assets through Long-Term Operation (LTO) programmes.

A more in-depth analysis of the geographical distribution of plants, using data from the International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS) updated in August 2025, reveals a marked dualism between the 'stock' of consolidated operating capacity and the 'flow' of new projects. The 'stock' remains concentrated in advanced economies: the United States leads with 94 reactors, followed by France with 57 and China, which with 57 operational reactors is now firmly among the leaders. In contrast, the "flow" of new capacity is almost entirely located in Asia and other emerging economies, with China as the undisputed leader in new construction, followed by India, Turkey, Egypt and Russia (IAEA, 2025). The following table not only lists these data, but also integrates qualitative and quantitative variables that are crucial for a comparative analysis..

Analysis of the table immediately reveals the macro trends that define the current nuclear era. On the one hand, the Average Fleet Age highlights the structural vulnerability of the United States and France. On the other hand, the youth and dynamism of the Chinese fleet emerges. The Reactors Under Construction column clearly shows that the epicentre of growth is now in Asia. Finally, the Main National Strategic Driver column shifts the analysis from 'what' to 'why', revealing how the motivations behind nuclear choices are profoundly different.

This geographical asymmetry is not a reflection of a technological gap, but rather a mirror of a divergence in institutional and political-economic models. The global nuclear map is being redrawn by the different capacities of states to structure and politically support capital-intensive infrastructure projects. The analysis reveals the existence of three competitive paradigms.

The epicentre of nuclear growth is Asia, with China leading an unprecedented expansion. Its strategy is a model of state-planned industrial policy. It is not, as in Western democracies, simple public support, but a vertically integrated national strategy in which state-owned enterprises (SOEs) such as CNNC and CGN act as instruments of the state (VIF, 2025). These entities manage the entire value chain, from design (such as Hualong One) to engineering and construction (EPC), while the state takes care of financing (VIF, 2025). The 14th Five-Year Plan (2021-2025) sets a target of reaching 65 GW of capacity by the end of 2025, an intermediate step towards overtaking the United States by 2030. This domestic strategy is inextricably linked to the global ambition expressed through the Belt and Road Initiative (BRI). Beijing's goal of supplying approximately 30 reactors to BRI countries by 2030 demonstrates how nuclear exports are a tool of long-term energy diplomacy, aimed at creating a system of strategic interdependence (VIF, 2025). Similarly, India's strategy has been accelerated by the 'Nuclear Energy Mission for Viksit Bharat', which aims for 100 GW by 2047, opening up to private involvement and investment in Small Modular Reactors (SMRs).

Faced with the rise of Asia, traditional nuclear powers are recalibrating their strategies. The US model is based on catalysing the market through policy. The Inflation Reduction Act (IRA) of 2022 does not nationalise the industry, but uses strong financial incentives such as the Production Tax Credit (PTC) to reduce project risk and stimulate private investment (Nuclear Innovation Alliance, 2023). The US industry is experiencing a 'renaissance' driven by two factors: the explosion in demand for electricity from data centres (AI) and the geopolitical imperative to counter Russia and China. This approach does not seek to replicate the Chinese model, but to exploit the inherent strength of the American system: deep capital markets and an economy driven by private innovation. France is also pursuing a dual objective: maximising the value of its existing fleet and launching a new programme to build EPR2 reactors, focusing its policy on energy sovereignty.

The third model is the Russian one, which combines state ownership with an aggressive export strategy with strong geopolitical connotations. The main player is Rosatom, a state-owned conglomerate which, through its Build-Own-Operate (BOO) model, has established itself as the global export market leader, controlling around 70% of new projects (IAI, 2024). The cases of Akkuyu in Turkey and El Dabaa in Egypt illustrate the logic of the model. At Akkuyu, Rosatom is financing, building, 100% owning and will operate the plant, creating a critical foreign-owned infrastructure on Turkish soil. Similarly, at El Dabaa, Russia is financing 85% of the cost through a state loan, providing a turnkey package that includes construction, fuel and maintenance. This approach eliminates the initial financial burden for the host nation but creates a strategic dependency (financial, energy, technological) that can last up to a century, transforming a commercial transaction into formidable political leverage (IAI, 2024).

The repurchase of such a dominant position by nuclear power is not a monolithic phenomenon, but a fragmented landscape defined by these three competing political-economic paradigms. The choice of a nuclear technology supplier today is, fundamentally, the choice of a long-term strategic partner, with profound implications for energy security, foreign policy and industrial development.

2.2 Finance and system value as the real bottleneck

The main barrier to the construction of new nuclear power plants in market economies is not technology, but finance. Nuclear projects are characterised by extremely high initial costs, long construction periods during which they generate no revenue, and an operating life cycle that extends over more than sixty years. This financial structure makes them exceptionally sensitive to the cost of capital (WACC). As highlighted in OECD-NEA literature, even modest changes in the cost of capital can drastically alter the levelised cost of energy (LCOE), a metric that calculates the average cost per megawatt hour produced over the entire life cycle of a plant, and compromise the profitability of an entire project (OECD-NEA, 2024). Consequently, non-European countries that are successfully relaunching their nuclear programmes are not doing so through revolutionary technological breakthroughs, but through the implementation of sophisticated institutional and financial frameworks for risk mitigation, designed to identify, allocate and mitigate key risks that would otherwise make projects unfinanceable by the private sector (OECD-NEA, 2024).

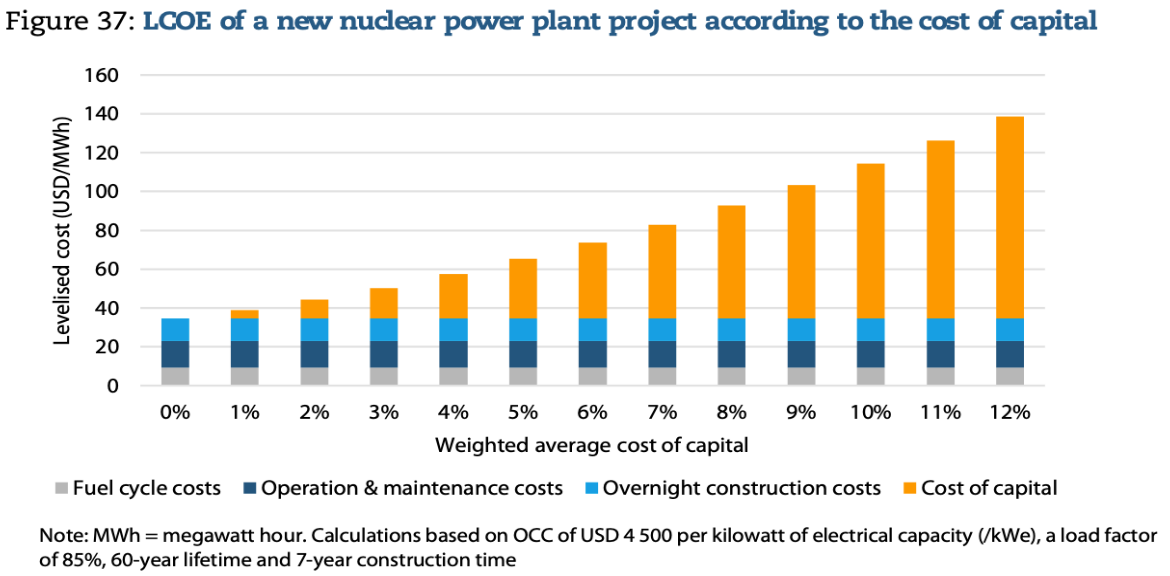


Figure 4- Sensitivity of nuclear LCOE to WACC: as the cost of capital increases, the financial component dominates the levelised cost, highlighting why de-risking schemes (RAB, CfD, guarantees/loan guarantees) are crucial for bankability. Source: OECD-NEA (2020), Fig. 37, pp. 110–111

A comparative analysis of these models reveals a pragmatic approach that moves away from relying exclusively on the market to embrace forms of public-private partnership. The goal is not to eliminate risk, but to manage it intelligently, allocating it to the actor, whether government, consumers or investors, best positioned to absorb it.

The UK has institutionalised bankability through its Civil Nuclear: Roadmap to 2050, which sets the ambitious target of achieving 24 GWe of nuclear capacity by 2050 (UK Government, 2024). To achieve this, the British government has developed two financial instruments, each aimed at neutralising a specific source of risk, which thus complement each other. The first model is the Regulated Asset Base (RAB): this instrument is designed to mitigate construction risk. Unlike traditional models, the RAB allows the project to receive a regulated revenue stream from electricity tariffs already during the construction phase. The strategy aims to solve the critical problem of financing an asset that inevitably does not generate revenue and does not cover costs for years, drastically reducing the burden of accumulated interest and lowering the cost of debt. The risk associated with possible delays and cost overruns is thus partially transferred to the tariff base, under the supervision of an independent regulator who ensures the efficiency of expenditure (UK Government, 2024; Ofgem, 2025).

The second model consists of 'Contracts for Difference' (CfDs): this mechanism is designed to mitigate market price risk. The CfD guarantees the producer a fixed price for electricity (strike price) over a long period (e.g. 35 years for the Hinkley Point C project). If the wholesale price of electricity falls below the strike price, the producer receives the difference; if it rises above it, the producer returns it to consumers. This instrument eliminates uncertainty about future revenues, protecting investors from the volatility of energy markets and making the financial returns of the project predictable, thus making the project bankable and more reliable (UK Government, 2014).

Canada has adopted an approach focused on reducing regulatory risk, a factor that often contributes significantly to project uncertainty and costs, including in Europe, and Canada could therefore be seen as a model. The country's SMR Roadmap and Action Plan base their approach on creating a predictable and efficient regulatory environment as a pillar of its nuclear strategy (Government of Canada, 2022). The key tools adopted here are the pre-licensing process and Vendor Design Review managed by the Canadian Nuclear Safety Commission (CNSC). This process allows technology suppliers to submit their reactor designs to a thorough regulatory review before a utility commits to a specific project on a site. This approach cleverly transforms regulation from a potential obstacle into a de-risking tool: it drastically reduces uncertainty about approval times and requirements and allows any design issues to be identified and resolved in a timely manner. This will give investors greater confidence in the feasibility of the authorisation process and provide them with more incentive to invest in a project that is perceived as safer.

The United States combines market incentives with targeted public credit support to overcome the financing difficulties of first-of-a-kind (FOAK) projects, considered one of the main obstacles to installing new capacity. At the heart of this approach is the intervention of the Department of Energy's Loan Programmes Office (LPO). Rather than replacing the market, the LPO acts as a guarantor, providing private investors with the confidence they would otherwise lack. Through programmes such as Title 17, it can intervene in two ways: either by directly financing projects through the Federal Financing Bank, with the security of a full government guarantee, or, more frequently, by offering a partial guarantee (up to 90%) on loans granted by commercial banks. In practice, the government acts as a risk guarantor to the market, providing security to investors. In a financial system such as the American one, which is vast and liquid, where government bonds are the benchmark for risk-free investment, a public guarantee has a powerful effect. It immediately translates into much more favourable lending conditions: the interest rates charged by banks are drastically reduced (lower spreads) and repayment terms are extended (longer tenors), significantly reducing the overall cost of capital for the project. This mechanism lowers the overall cost of financing and makes projects bankable that, due to the perceived technological risk, the private market alone would not support (US DOE, 2025).

A prime example of efficient bankability outside Western models is South Korea's export of APR-1400 reactors to the United Arab Emirates. This project demonstrated how strong government support, an attractive financial package and a solid reputation for on-time and on-budget delivery can overcome market barriers (KEIA, 2015). This case serves as a bridge between the state-led models analysed earlier and the de-risking mechanisms analysed in this section, demonstrating that bankability is an engineered outcome, not a state of market nature.

These models demonstrate that the bankability of modern nuclear projects does not depend on a single instrument, but on a coherent financial and regulatory architecture, supported by long-term political commitment. The stability offered by these regulatory frameworks creates a virtuous circle: revenue predictability and risk mitigation lower the cost of capital, making projects financeable. A credible project pipeline, in turn, encourages investment in the supply chain, promotes standardisation and fosters learning curves, which, in the medium term, are the real drivers of cost reduction. Ultimately, finance and policy are not ancillary to technology, but constitute its fundamental enabling technology (OECD-NEA, 2024).

Until recent years, the economic assessment of nuclear energy has been dominated by the 'LCOE' metric, the Levelised Cost of Energy, which calculates the average cost per megawatt hour (/MWh) produced over the entire life cycle of a plant. This is very useful for comparisons between programmable technologies in a traditional energy system, but at the same time it is an inadequate and often misleading tool for analysing the complex dynamics of a decarbonised electricity system with high penetration of variable renewable energy sources (RES).

The OECD-NEA report entitled "The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables" argues that an analysis based solely on LCOE ignores the additional costs that different technologies impose on the entire electricity system to ensure reliable and continuous energy supply (OECD-NEA, 2019).

These "system costs", ignored by LCOE, arise mainly from the variability and non-programmability of wind and solar power: as sun and wind are variable sources, these costs should be taken into account.

The latter can be divided into three categories: Profile Costs arise from the time mismatch between RES generation (linked to sun and wind) and the electricity demand curve. This creates periods of surplus, when the market value of electricity collapses (sometimes becoming negative), and periods of deficit, which require the activation of backup capacity. Then there are Balancing Costs, which are the costs incurred to manage the short-term unpredictability of RES production, maintaining the balance between supply and demand on the grid at any given moment. Finally, there are grid costs, which include the investments needed to strengthen and extend transmission and distribution infrastructure, often to connect wind or solar farms located in remote areas to consumption centres (OECD-NEA, 2019).

The OECD-NEA analysis shows that, although all technologies have system costs, those associated with RES grow non-linearly with their penetration into the grid, accounting for a significant share of the total cost of decarbonisation. In contrast, it is precisely low-emission programmable technologies, such as nuclear and hydroelectric power, that represent costs of an order of magnitude lower for the system. Their ability to produce energy in a predictable and controlled manner reduces the need for fossil fuel backup capacity, expensive storage systems and massive investments in the grid, thus lowering the overall cost of achieving a given emission reduction target, such as only 50 gCO2/kWh (OECD-NEA, 2019).

Consequently, it is the overall economic assessment of nuclear power that must change paradigm and shift from an LCOE-based comparison to an analysis of its 'system value'. It is nuclear power that has the capacity to reduce the total cost of the system and provide essential services for grid stability, much more so than solar and wind power.

A central element of this system value is operational flexibility. The idea that nuclear power is a "rigid baseload" technology, incapable of modulating its output, is refuted by technical and operational evidence. The OECD-NEA report Technical and Economic Aspects of Load Following with Nuclear Power Plants documents in detail how modern light water reactors are technically designed to operate in load-following mode, actively contributing to grid stability (OECD-NEA, 2011). The technical capabilities are remarkable: modern reactors can vary their output by 3-5% of their power; they can then participate in both primary control, i.e. through a rapid response to frequency fluctuations, and secondary control, adjusting production at the request of the grid operator (OECD-NEA, 2011).

2.3 SMRs, diversified revenues and credible governance

The most significant economic innovation in the nuclear sector lies in the shift from a single-product (electricity) business model to a multi-product model that diversifies revenue streams, known as 'value stacking'.

This approach transforms a nuclear plant from a simple power station, exposed to the volatility of the wholesale market, into an integrated industrial energy hub, capable of supplying heat, hydrogen and other energy carriers through cogeneration. This strategy is supported by quantitative data and operational case studies that demonstrate its bankability.

The IAEA TECDOC-2056 report shows that in district heating, the Chinese plants in Qinshan and Haiyang have reduced heating costs for residents by up to 33% and cut CO2 emissions by tens of thousands of tonnes per year by exploiting waste heat that would otherwise be lost (IAEA, 2024). In Europe, too, a case study for Helsinki confirmed the economic competitiveness of nuclear district heating, while highlighting the need for small reactors to suit the size of local networks (IAEA, 2024).

In the industrial sector, the supply of process heat leads to stable revenues and long-term flows, decoupled from the electricity market. Historical examples such as the Stade plant in Germany and Gösgen in Switzerland, which supplied steam to local industries, demonstrate the technical and commercial feasibility of this model (IAEA, 2024). The ability to supply high-temperature heat is particularly strategic for the decarbonisation of *hard-to-abate* sectors such as chemicals and steel.

Hydrogen production is another promising frontier. Studies conducted in Canada, India and Japan quantify its potential: a 1 GWe reactor can produce approximately 150,000 tonnes of hydrogen per year (IAEA, 2024). In Japan, it is estimated that a high-temperature reactor (HTGR) can produce hydrogen at a competitive cost of 25 JPY/m3, making it a solution for decarbonising the steel industry.

The Japanese cost of 25 JPY/m³, converted to the standard units of measurement for the hydrogen market (dollars per kilogram), is equivalent to approximately $1.85/kg (assuming an exchange rate of 150 JPY/USD and a hydrogen density of approximately 0.09 kg/m³) (IAEA, 2024). Although this figure appears very competitive, the advantage of the American model lies in its nature and financial certainty.

The Japanese figure is a future projection, a cost target conditional on the successful construction and operation of an advanced technology (HTGR) that has not yet been implemented on a commercial scale. For an investor, this represents a very high technological and execution risk.

In contrast, the American incentive is a guaranteed and immediate tax credit. The Inflation Reduction Act (IRA) offers up to $3 per kilogram of clean hydrogen produced, a guaranteed cash flow from the federal government for 10 years (US Congress, 2022). In the United States, the Inflation Reduction Act has made nuclear hydrogen production even more attractive by offering a tax credit of up to $3/kg, which improves the business case for reactor operators (IAEA, 2024).

These figures transform the concept of 'system value' into a series of tangible cash flows. A financial model for a new nuclear project can now potentially include a 20-year steam supply contract with a chemical industry, an electricity PPA with the grid and potential revenues from the sale of hydrogen.

This diversification makes the project's revenue profile more predictable, reducing its perceived risk and, consequently, lowering the WACC.

Innovation, as mentioned, is as much financial and contractual as it is technological, redefining nuclear power as a versatile industrial infrastructure capable of attracting a wider range of investors if properly secured.

While the present of the nuclear sector continues to be defined by the optimisation of existing facilities and the construction of new large reactors, the most disruptive innovation is focused on a new class of technologies: Small Modular Reactors (SMRs). SMRs are not simply a reduction in scale compared to traditional reactors, but represent a fundamental change in the business model and value proposition of nuclear energy. They mark the transition from large, complex, one-off projects to standardised, versatile products designed to be integrated into energy ecosystems (WNA, 2024).

According to the World Nuclear Association's definition, SMRs are reactors with an electrical output of less than 300 MWe, designed to be factory-built as modules and then transported and assembled on site as needed. This modular approach aims to exploit the advantages of mass production, which include reduced construction times, improved quality control and lower costs through learning curves, typical of the manufacturing sector (WNA, 2024).

A case study emblematic of this philosophy is GE Hitachi's BWRX-300 reactor. This design is based on a principle of 'innovation by subtraction', i.e. instead of adding complexity, it radically simplifies the reactor by exploiting established physical principles. It uses natural circulation for core cooling, eliminating the need for large recirculation pumps, associated piping and support systems. Safety is ensured by passive systems which, in the event of an emergency, use gravity and steam condensation to cool the reactor for days without the need for external power or human intervention (GE Vernova, 2025).

This simplification results in a significant reduction in the volume of the reactor building and the amount of concrete and steel required for construction. This makes the cost of the reactor per MWe competitive and the construction time shorter and more predictable. The ultimate goal is to transform the reactor from a bespoke engineering design into a standardised industrial 'product', whose cost and reliability improve with each unit produced, in line with the serialisation strategies pursued by countries such as Canada and the United Kingdom (GE Vernova, 2025; UK Government, 2024; Government of Canada, 2022).

However, the Western competitive landscape is not very differentiated. An alternative approach is represented by Westinghouse's strategy for its AP1000 reactor. Technically, it is a medium-sized reactor, but its design structure, which emphasises standardisation, modular construction, passive safety and a small footprint, makes it a direct predecessor and competitor of SMRs.

The market strategies of the two main Western players diverge significantly. GE Hitachi, with its BWRX-300, is building broad international coalitions and local supply chains in countries such as Canada, Poland and the UK even before starting construction of the first unit, creating an ecosystem of collaborations (GE Vernova, 2025). Westinghouse is opting for a different strategy, leveraging its history and existing (albeit troubled) reference plants in the United States (Vogtle) and China (Sanmen, Haiyang) to sell a 'proven' design to new markets such as Poland and Ukraine. These two paths illustrate different marketing strategies: one based on creating a broad and collaborative ecosystem, albeit still 'in potential', the other on consolidating an existing product line.

The real revolution of SMRs, however, lies in their functional flexibility, which opens up the business model based on revenue diversification, or 'value stacking', discussed earlier. Unlike large reactors, whose sole function is to feed electricity into the transmission grid, many SMRs are designed as energy hubs, capable of providing multiple products. These products are primarily programmable electricity, which consists of providing stable energy to the grid, complementary to renewable sources. Then there is high-temperature process heat, i.e. supplying steam to energy-intensive industries (chemicals, steel, cement production), enabling the decarbonisation of hard-to-abate sectors. Another product offered is district heating, providing low-emission heat for urban heating networks. An important and increasingly developing area will be hydrogen production, which will power high-efficiency electrolysers to produce clean hydrogen for use as an energy carrier or industrial raw material. The final product is desalination, providing the energy needed for water desalination plants (IAEA, 2024; OECD-NEA, 2020).

This 'multi-product energy hub' model creates an inherently stronger business case. The diversification of revenue streams acts as a natural hedge against the volatility of individual energy commodity markets. It transforms SMRs from simple power plants into powerful industrial infrastructure capable of attracting a wider range of investors and partners, including large industrial companies and funds, seeking stable, long-term returns. SMRs are therefore not only a technological innovation, but above all an economic and strategic one, redefining the role and value of nuclear power within the energy system of the future (IAEA, 2024).

The Role of Nuclear Power in the Path to Net Zero: The position of the International Energy Agency (IEA) is unequivocal: achieving the goal of net zero emissions by 2050 will be 'more difficult, more risky and more expensive' without a significant contribution from nuclear power.[31] The path outlined by the IEA requires a doubling of global nuclear capacity between 2020 and 2050.[31] Nuclear power is recognised as the only low-carbon energy source that is both scalable and dispatchable, acting as an indispensable complement to intermittent renewable sources.

Despite renewed interest and technological innovation, nuclear energy continues to face significant barriers in public and political perception, mainly focused on plant safety and radioactive waste management.

A thorough examination reveals that these are not unresolved technical issues, but complex governance challenges for which there are already established technical solutions and robust international regulatory frameworks. The critical variable determining success is not the absence of solutions, but the quality, stability and credibility of the national institutions responsible for their implementation.

Nuclear safety is often perceived as an abstract and indefinable concept, but in reality it is codified in an architecture of globally recognised principles and standards, centred on the work of the IAEA, which are, however, little known and disseminated.

The *Fundamental Safety Principles* (IAEA Safety Standards Series No. SF-1) form the basis of this system, establishing ten principles that define a comprehensive approach to safety (IAEA, 2006). Among these ten, three are particularly relevant for framing safety as a governance process. The first concerns responsibility for safety: ultimate responsibility for safety lies with the plant operator and cannot be delegated. The second principle focuses on the role of government: each state must establish a robust legal and regulatory framework, including an independent, competent and adequately resourced regulatory authority. The eighth principle focuses on accident prevention: safety must be ensured through the concept of 'defence-in-depth', which provides for multiple and independent levels of protection to prevent accidents and mitigate their consequences (IAEA, 2006).

The existence of this detailed and internationally agreed framework shifts the debate from a generic and difficult-to-define question, such as whether nuclear power is safe, to a series of concrete and verifiable governance issues. In fact, the national regulatory body has the necessary independence and competence if the principles of defence are rigorously applied and are definable and quantifiable, unlike a generic concept of 'safety'. The concept of 'safety' itself could be identified and quantified in a question such as: 'Is there a strong safety culture within the operator's organisation?’

Safety, therefore, is not an intrinsic property of technology, but the result of a high-quality, transparent and continuously reviewed governance process (IAEA, 2006).

The second major critical issue perceived is the long-term management of spent fuel and high-level waste. Here too, the international scientific community has reached a consensus on a safe and definitive solution by establishing the conditions for deep geological disposal (GDF).

The IAEA defines IAEA safety standards (such as SSR-5 and SSG-14) and the requirements for the design, siting and management of a GDF. It is based on a dual approach, integrating both engineering solutions such as containers and backfill materials, and natural elements such as the stable geological formation chosen to host the repository. Both types of solutions ensure the isolation of waste from the biosphere for millennia (IAEA, 2011).

The technology for building a GDF is actually mature and already being implemented in countries such as Finland and Sweden. The real challenge is not technical, but socio-political and financial.

The main obstacle is usually a country's actual ability to carry out a transparent localisation process based on the consent of local communities and to establish a stable financing mechanism that can cover the costs of the project over a very long time horizon.

A good example of integrated governance is that of the United Kingdom. The document "Civil Nuclear: Roadmap to 2050" not only promotes the construction of new reactors, but explicitly links this commitment to a structured and funded programme for the creation of a Deep Geological Repository (GDF) (UK Government, 2024). End-of-life management is treated as an integral part of the nuclear life cycle and its costs have already been accounted for. Dedicated funds are being set up, financed by a levy on electricity produced, to ensure the availability of the financial resources necessary for the decommissioning of plants and waste management (UK Government, 2024). This approach makes it possible to transform what is perceived as an indefinite liability and a burden on future generations into a long-term infrastructure project that is defined, planned and fully funded.

However, the biggest unresolved governance challenge for a real revival of nuclear power in the West is not, once again, technical or related to public perception, but concerns the strategic fragility of its industrial base and fuel supply chain.

The long hiatus in the construction of new nuclear power plants in the West, beginning in the 1980s, triggered a gradual weakening of its specialised industrial base, with strategic consequences that are evident today (WNA, 2015; IEA, 2025). A key point of this fragility concerns the production of large *forged components*. These are enormous blocks of steel, such as the reactor pressure vessel that forms the heart of the reactor, which are shaped at extreme temperatures and pressures to create a single piece without welds. Their absolute integrity is a non-negotiable safety requirement as they must contain the nuclear reaction flawlessly for decades (WNA, 2024).

This capability, which requires extremely powerful presses and highly specialised skills, has declined significantly in Europe and North America since the 1980s. The decline in orders has led to the closure or downsizing of various sites and the departure of skilled workers, creating a generational gap in the supply chain. However, some Western centres remain, while over the last two decades Russia and China have developed capabilities for large forgings, filling the void that had been created (WNA, 2024). The market has therefore shifted and for decades has been dominated by Japan Steel Works (JSW), which came to control about 80% of world production. As Western capacity waned, countries such as Russia (with OMZ Izhora) and China (with China First Heavy Industries and China Erzhong) developed their own supply chains to support their national programmes (WNN, 2009).

This has created a new strategic dependency: today, any nuclear expansion programme in the West faces a production *bottleneck*, having to rely on a small number of global suppliers, some of which are located in complex geopolitical contexts.

This vulnerability extends to the entire fuel cycle. Many of the advanced reactors and new-generation SMRs require a specific fuel, High-Assay Low-Enriched Uranium (HALEU) (IAEA, 2023). Until recently, the only commercial supplier of HALEU on an industrial scale was Russia, an unacceptable strategic dependency in the current geopolitical context (EPRS, 2024). The European Union and the United States have responded to this need and launched urgent initiatives to develop domestic production capacity, with the the Inflation Reduction Act (2022) allocating about $700 million to HALEU supply-chain development (EPRS, 2024). The supply of natural uranium is also subject to geopolitical risks, as demonstrated by the 2023 coup in Niger. The African nation was a key supplier to the European Union, covering more than 25% of its needs in 2022, and the resulting political instability disrupted the operations of the French company Orano, highlighting the fragility of supply chains that depend on unstable regions (TRT World, 2024).

With these considerations in mind, it is clear that effective, long-term governance of a nuclear programme must go beyond operational safety and waste management. It must include an industrial and resource procurement strategy that actively manages supply chain bottlenecks and geopolitical risks.

The inability and unwillingness to preserve an industrial base and fuel cycle has transformed a commercial issue into a national security vulnerability, which today represents the most concrete and complex obstacle to the future of nuclear power in the West.

Chapter 3: Italy's Vulnerability, Strategy and Industrial Positioning

To fully understand the complexity of the Italian debate on nuclear power, it is essential to analyse its historical trajectory, marked by initial technological leadership, two abrupt interruptions and a recent, cautious rapprochement.

This represents a legacy that still influences public perception, political dynamics, and legislative and institutional processes today.

3.1 Italy's nuclear trajectory from exogenous shocks to strategic policy coherence

In the recent past, Italy was a pioneer in the field of atomic energy: in 1965, it was the world's third largest producer of nuclear energy, after the United States and Great Britain, demonstrating its first-rate scientific and industrial expertise. This long period of stability was interrupted in 1987 by the Chernobyl disaster, which acted as an exogenous shock, capturing public and political attention. The impact of the accident, amplified by a debate that intertwined legitimate safety concerns with broader criticism of the industrial development model, culminated in the November repeal referendum. Although the referendum focused on specific regulations, it was interpreted as an unequivocal political mandate to abandon nuclear power.

A second attempt at relaunching the programme was made in the late 2000s, but this too was abruptly interrupted in March 2011 by the Fukushima Daiichi accident. Media coverage of the Japanese disaster reactivated latent fears in public opinion, triggering a new, rapid change that led to the June referendum. These events are a clear example of the *punctuated equilibrium* policy model, in which long periods of political stagnation are broken by sudden and radical changes, triggered by exogenous shocks that alter the perception of risk (Baumgartner and Jones, 1993). As Newcleo observes, 'emotion-driven choices in politics come at a high cost' (Newcleo, 2024, p. 12). This statement introduces the central thesis of this chapter: Italy's current nuclear strategy represents an attempt to move from a policy model susceptible to exogenous emotional shocks to one based on long-term techno-economic rationality. However, it is crucial to note that from a purely legal point of view, the door has never been definitively closed. A ruling by the Constitutional Court has clarified that referendums abrogative referendums do not prevent the legislator from legislating again on the matter if the factual, technological or political conditions change (Constitutional Court, 2012). This principle is the legal basis that legitimises the current debate on the return to nuclear power.

Today's political context is, in fact, profoundly different. The energy crisis of 2022, the urgency of decarbonisation and advances in SMR technologies have shifted the most pressing issues in the political debate. The current government, led by Giorgia Meloni, has taken an openly favourable position, framing nuclear power as a key element for energy security and also for climate neutrality. This position is supported by a solid parliamentary majority that includes parties such as Forza Italia and the Lega, historically pro-nuclear, and centrist parties such as Azione and Italia Viva. On the opposite side are the Green Left Alliance and the Five Star Movement, which remain firmly opposed, while the Democratic Party, although opposed to fission, is open to research on fusion. [1]

This new political balance, combined with a shift in public sentiment, with growing support, especially among younger people, has created a window of political opportunity that has not been seen for decades.

3.2 An import dependent electricity system and the determinants of price volatility

In the complex European energy landscape, Italy occupies a peculiar position, defined by a structural condition that determines both its vulnerabilities and its strategic needs.

Although the country is a major manufacturing economy, it is chronically dependent on energy imports and, as a result, acts as a price-taker. This term refers to a market player that, due to insufficient domestic generation capacity, does not have the bargaining power to set its own energy

[1] data from direct interview and company presentation, Newcleo

prices. As a result, it is forced to accept these prices as an exogenous variable, defined by the dynamics of surrounding and international markets. This dependence is a fundamental characteristic of the national energy mix.

The consolidated data confirms this profile of strong exposure to foreign markets. In 2023, foreign trade covered 51.3 TWh of demand, equal to 16.8% of total electricity consumption (Terna, 2024); trade was mainly concentrated with neighbouring countries, with France playing a prominent role. On the one hand, interconnections act as an important buffer for both prices and system adequacy; at the same time, however, they transfer added value abroad and import volatility resulting from decisions taken beyond national borders.

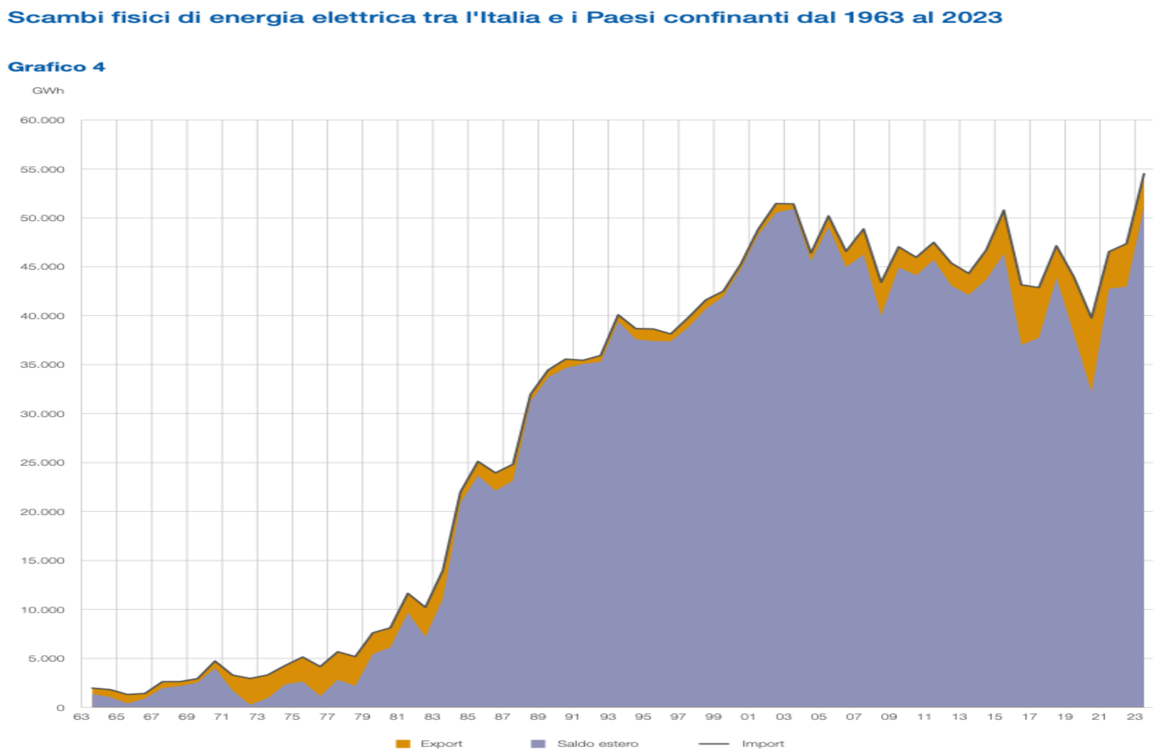


Figure 5 - Net electricity import/export position of EU countries (Q1 2025 vs Q1 2024): Italy is the main net importer (13 TWh), confirming its structural dependence; slight improvement compared to Q1 2024.

This fragility is confirmed and even accentuated by more recent developments, including in the energy sector. In the first quarter of 2025, Italy established itself as the European Union's main net importer, with approximately 13 TWh of energy purchased. At the continental level, there was also a record high number of hours at negative prices in the *day-ahead* market, signalling a system that alternates between excesses of non-programmable renewable generation and periods of scarcity that network infrastructure, storage and flexible demand are not always able to absorb (DG ENER, 2025).

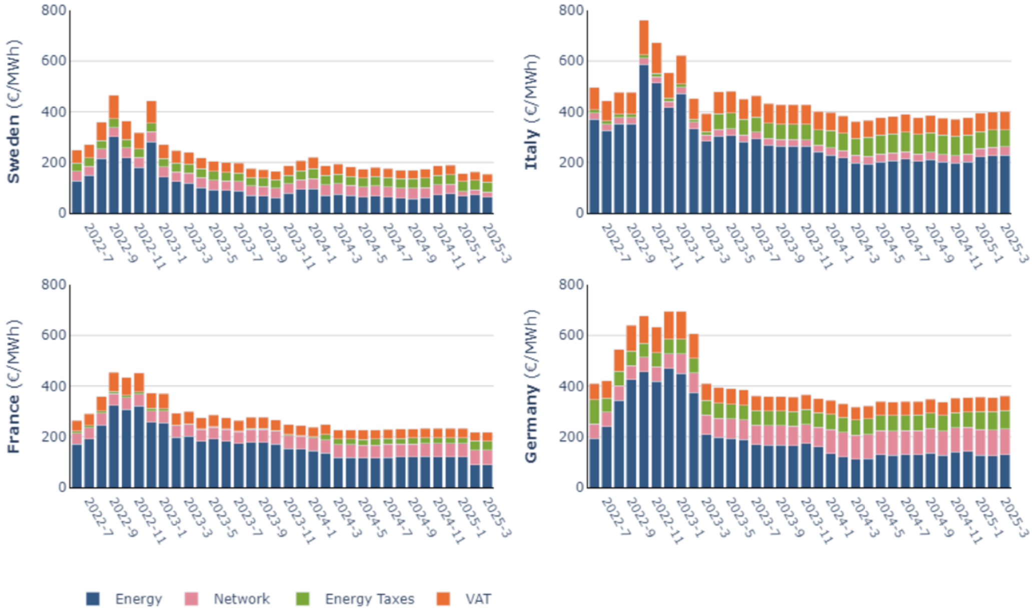
Over a longer time horizon, by mid-2025, approximately 15.4% of Italian demand will be covered by imports, in line with the 16.3% recorded in 2024 (Terna, 2025), confirming the structural nature of Italy's dependence.

Our country, severely unbalanced on the import side and necessarily operating in a very unstable market, finds itself importing the uncertainty of others; the direct consequences are reflected in domestic prices, with increasing difficulty in planning long-term coverage.

The most worrying fact is that this vulnerability inevitably affects the competitiveness of the industrial system. Eurostat's official and harmonised data on final electricity prices for industrial consumers speak for themselves. In the second half of 2024, compared to a cost in Italy of €0.22/kWh (€220/MWh), companies in Germany paid €0.19/kWh and those in France just €0.13/kWh (Eurostat, 2025). This cost differential represents a real 'implicit tax' on production, which slows down investment and undermines the competitiveness of Italian SMEs on international markets.

- **Figure 31** shows industrial SMEs (IB Band) electricity prices for selected Member States across the years. End user prices in Italy were at 400 €/MWh, which is more than in Germany (360 €/MWh), France (217 €/MWh) and Sweden (154 €/MWh). While prices in Italy and Germany rose slightly compared to previous quarters, prices in Sweden and France remain on a downward trajectory.

Figure 31 –Industrial retail prices for SMEs in selected EU countries



Source: VaasaETT

Such a marked differential, which persists even after the energy component costs have been recouped, cannot be attributed solely to raw materials but reflects a complex set of factors. Cost analysis shows that they are mainly attributable to system charges, network costs, taxation and a lower prevalence of long-term supply contracts (PPAs), which amplify the transmission of shocks from the wholesale market to the final bill (MASE-RSE, 2025).

To fully understand how volatility is passed on to tariffs, it is necessary to analyse the microstructure of retail markets. Joint ACER-CEER reports highlight how the 2021–2023 energy crisis has put a strain on suppliers' hedging schemes (ACER-CEER, 2024).

In markets where variable-price offers indexed to wholesale prices prevailed, the impact of the increase was passed on to consumers almost instantly. Conversely, where long-term fixed-price offers dominated, the impact was delayed but manifested itself more abruptly at the time of contract renewal. The gradual *phase-out* of emergency measures in 2024–2025, such as temporary cuts in taxes and levies, explains why retail prices have risen slightly in many EU countries despite the fall in the energy component and why price trajectories now remain uneven across Member States. Italy is more affected by the 'permeability' of the final tariff to wholesale market shocks.

The heart of the problem lies in the centrality of natural gas and the marginal price formation mechanism. On the Italian electricity exchange, the Single National Price (PUN) for a given hour is not determined by an average of production costs, but by the cost of the last and most expensive generation unit needed to meet demand (the *price-setting* source). Given the structure of the Italian generation fleet, this unit is typically a gas-fired power plant. This results in a close and almost inseparable correlation between the price of gas (TTF) and the PUN (RSE, 2024).

Even at times when 90% of electricity is produced from renewable sources at almost zero marginal cost, the price for all traded energy is set by the operating cost of the gas-fired power plant that 'finishes' covering demand.

The effect of this mechanism is amplified: for example, a €1/MWh increase in the price of gas can translate into a price increase of up to €2/MWh in the PUN. This creates an apparent anomaly: the system becomes cheaper to operate on average thanks to renewables, but the price signals it sends to the economy remain costly and volatile, preventing the benefits of the transition from being fully realised and sending signals to potential investors who would like to invest in green h s. Although Europe has responded with a structural reduction in gas consumption (approximately -18% for the EU and UK between 2022 and 2024), this is not enough to neutralise episodes of tension (Bruegel, 2024): as long as gas remains the price-setting element at critical times, its peaks are quickly reflected in the PUN, keeping volatility high.

These microeconomic findings are fully consistent with the macroeconomic diagnosis formulated in the Draghi Report on European competitiveness (Draghi, 2024).

The report highlights how the EU suffers from structurally higher and more volatile energy prices than the United States and China, how the crisis has widened internal divergences between countries, and how the fragmentation of the capital market raises the cost of capital (WACC) for the capital-intensive projects needed for the transition.

A single capital market, unlike a fragmented one, removes national barriers that limit the flow of investment and capital. This ensures greater liquidity, improves risk distribution and increases competition, reducing financing costs for businesses. By combining markets, businesses can access a larger pool of investors, reducing costs and obtaining the necessary capital more efficiently. A unified market consolidates capital into a single European investment pool, increasing the liquidity of the system and enabling even very large and complex projects to be financed.

Risk diversification makes the European financial system more resilient to economic shocks that could affect a single country.

Applied to the Italian case, this diagnosis implies that an import-dependent, price-taking country pays a higher price in times of scarcity, fails to fully capture the benefits in times of overproduction by others, and struggles to mobilise capital for transformative investments, precisely because the cost of capital is not stabilised by common instruments and deep financial markets.

Added to this is an uneven fiscal and institutional profile: the various national measures adopted during the 2022–2023 crisis, while temporarily cushioning the social impact, created further divergences between markets, whose gradual withdrawal is now revealing structural cost differentials for businesses (Draghi, 2024).

This situation has given rise to the 'renewable growth paradox': while it is true that Italy has accelerated installations, this expansion has not yet translated into full energy independence, as the price formation mechanism remains anchored to marginal fossil fuels. , this triggers a vicious circle in which volatility and high price levels act as an 'implicit tax' on the industrial base, draining resources from other investments in research, development and decarbonisation. Businesses are forced to prioritise short-term survival over long-term strategic investment.

A genuine paradigm shift is needed to break this vicious circle. The intelligent use of interconnections remains a necessary but no longer sufficient condition. In a Europe characterised by frequent negative price hours alternating with peaks of scarcity that would cause prices to skyrocket, domestic stability requires the construction of a solid internal supply of programmable *low-carbon* capacity (*clean firm)*, capable of compressing price dispersion, reducing risk premiums in contracts and aligning investment expectations.

It is also crucial to reduce investment risk (*de-risking*) through a deep market for long-term purchase agreements (PPAs), which offer stability to consumers and revenue certainty to investors.

As the Competitiveness Report emphasises, strategic investments and network planning at national and European level are essential to reduce congestion and strengthen critical interconnections. The deployment of flexibility and storage solutions (such as large-scale batteries and *demand-side response*) should also be accelerated to counteract the intermittency of renewable sources.

Ultimately, the goal is to reform the market design in such a way that, while preserving short-term efficiency, it allows the remuneration of low-operating-cost technologies, such as renewables, to be decoupled from that of fossil fuels, shifting the focus from emergency price management to the structural design of the energy system. This is the profound meaning of the 'true Energy Union' advocated by Draghi: a stable regulatory framework capable of attracting private capital to the necessary infrastructure (Draghi, 2024).

3.3 National industrial strategy within an enabling framework for nuclear investability

Faced with this diagnosis of vulnerability, Italy's trajectory towards climate neutrality has begun to take on a more defined profile, shifting the debate from an abstract assessment of scenarios to a concrete industrial policy.

In the national plan, the nuclear option has been formally reopened, not as an alternative to renewables, but as a strategic complement to them. This is to ensure stability and economic efficiency for the system.

The 2024 Integrated National Energy and Climate Plan (PNIEC) introduces for the first time a 'with nuclear' scenario, in which 8 GW of capacity, including approximately 1.3 GW in cogeneration to provide heat to industry, would cover approximately 11% of electricity demand by 2050 (MASE, 2024). Cogeneration, or combined heat and power (CHP), is a process that recovers the residual heat generated during electricity production for use, for example, in heating or industrial processes, thereby improving overall energy efficiency.

This scenario, based on models that minimise overall system costs, highlights how the presence of a programmable low-emission source reduces the need for gas with CO2 capture and limits the overproduction of renewable energy (*overgeneration*), which would otherwise be wasted.

The National Platform for Sustainable Nuclear Energy (PNNS), set up to act as a 'control room', has further quantified the economic reasons for this choice. According to the Platform's analysis, the 'conservative' scenario with nuclear power would result in a saving on the total cost of achieving Net Zero of around €16 billion compared to the scenario without nuclear power, a difference that rises to €17 billion if the lower *overgeneration* is also taken into account (PNNS, 2025).

These figures formalise a fundamental economic principle: in a system with high renewable energy penetration, the value of programmable capacity (nuclear in this case) lies in its ability to reduce system costs (backup, storage, network congestion), a benefit that traditional metrics such as LCOE do not fully capture.

The industrial component of this strategy took shape in May 2025 with the creation of Nuclitalia, a joint venture between Enel (51%), Ansaldo Energia (39%) and Leonardo (10%) (Enel, 2025). Nuclitalia's mandate is clear and strategic: to evaluate the most mature reactor designs, with an initial focus on water-cooled SMRs; then to define the specific requirements for the Italian context and select 'bankable' solutions, including through partnerships and co-design with the national supply chain.

Its creation responds to a critical need: to centralise technology scouting and technical specifications in order to avoid fragmentation, reduce information asymmetries and create a single, credible interlocutor for international suppliers. In a sector such as nuclear power, which is focused on learning curves and serialisation, this approach is a prerequisite for shortening the distance between political will and concrete industrial implementation.

At the same time, on the demand side, there are signs of alignment among the major utilities. Edison, for example, has declared its ambition to build two SMR plants by 2040, replacing end-of-life combined cycle gas plants, with a clear intention to enhance the Italian supply chain (Edison, 2025).

This sign of '*anchor demand*' is crucial, because it is the prospect of a credible order pipeline that can justify the investments needed to reactivate and upgrade the national supply chain.

Anchor demand is a large initial and guaranteed request from a major player (corporate or institutional, in this case Edison), which serves to send a signal of confidence to the market.

It acts as an "anchor" for investors, reducing uncertainty and encouraging them to finance the projects needed to meet future demand. This signals to investors that their investment is safer, as demand is already "anchored" and not subject to market uncertainties. It therefore reassures operators in the supply chain that there will be future demand for their products, making their investments economically sustainable.

The joint report by Confindustria and ENEA (July 2025) reinforces this new direction, linking the PNIEC trajectory to the construction of a genuine industrial ecosystem, coordinated at European level through the new European Industrial Alliance on SMRs to overcome bottlenecks in the supply chain, regulation and capital (Confindustria-ENEA, 2025).

The Italian strategy is currently based on four pillars: energy planning that quantifies the systemic benefits of nuclear power; an industrial vehicle (Nuclitalia) that centralises technology selection; demand signals from utilities; and a public-private coalition that links up with European networks to achieve the necessary scale.

There are still unknowns: authorisation times, revenue stabilisation and risk governance. These are and remain significant, but the gap between analysis and execution has narrowed considerably, shifting the focus to the ability to translate this architecture into a credible set of projects.

An industrial strategy remains only a theoretical exercise without a regulatory and administrative 'drive belt' capable of translating it into practice. Italy's new nuclear policy hinges precisely on this enabling framework, the architecture of which is defined by the enabling law approved in 2025 (Italian Government, 2025). This measure is not a law but a mandate to the Government to define, within twenty-four months, the entire legal framework for sustainable nuclear power: from siting to construction, from operation to waste management, to *decommissioning*.

If this ambitious timeline is met, it can provide the necessary procedural certainty that is a fundamental prerequisite for 'de-risking' and attracting the capital-intensive investments required for nuclear power.

At the institutional level, the delegation provides for the reorganisation of competences relating to safety and supervision, which are crucial for the credibility and implementation of the system. The

National Inspectorate for Nuclear Safety and Radiation Protection (ISIN), operational since 2018, is already the competent authority for technical regulation and binding opinions (ISIN, 2025).

The implementing decrees will therefore need to strengthen its independence, resources and investigative capabilities, transparently defining its relations with ministries and the political steering committee (the PNNS). Following this path should reduce the regulatory risk perceived by investors.

Bilateral cooperation agreements, such as the one already in place between ISIN and its French counterpart (ASN), are of strategic importance here. These agreements, which facilitate the exchange of technical information and common practices, do not replace national investigations but reduce their duration and uncertainty, thereby reducing technical risk and delays, with a direct impact on reducing the cost of capital (WACC) for *first-of-a-kind* projects.

However, the most delicate issue that the delegation is called upon to resolve is procedural. The National Platform for Sustainable Nuclear Energy (PNNS) has correctly identified the regulatory 'void' regarding location and has proposed a multi-stage process: informal *pre-licensing* with suppliers to standardise the reference design, followed by formal *pre-licensing* with operators integrated with environmental assessments (VAS/VIA), and then a 'step-by-step' authorisation for the specific site (PNNS, 2025). Establishing a delegation for authorisation, with clear deadlines and administrative responsibilities, is necessary to transform these good practices into operational rules.

The idea of a *one-stop shop* based on the European Clean Industrial Deal State Aid Framework (CISAF) model, which acts as a single interface for operators, is the most effective solution for reducing administrative and political risk, cutting down on the sequential nature and duplication that have scuppered major infrastructure projects in the past. 'Sequentiality' refers to the bureaucratic process in which approvals and authorisations must be obtained one after the other, from different authorities and at different times. A single point of contact, on the other hand, allows the entire process to be managed in a coordinated and parallel manner, overcoming the complexity and slowness of this approach (European Commission, 2024).

The new administrative architecture will have to be fully aligned with the *acquis* communautaire. The Euratom directives on safety and waste management have already been integrated into Italian law, and therefore delegated decrees can be based on solid foundations, ensuring clear coordination with the National Programme for Radioactive Waste Management, while accelerating the construction of the National Repository. (MASE, 2025). This achievement remains fundamental to the credibility of the entire programme.

The explanatory report to the enabling law opens the way for the definition of 'support mechanisms' consistent with the electricity market (Italian Government, 2025).

I will analyse the specific instruments in Chapter 4, but I can anticipate here that compatibility with the objectives of the enabling law implies the adoption of mechanisms that stabilise long-term revenues, reduce construction risk and enhance the positive externalities of *clean firm power*, all in compliance with EU state aid rules.

In summary, the delegation provides the legal architecture; it will be the implementation through implementing decrees that will determine whether Italy will be able to create an investment-friendly environment capable of reducing the cost of capital (WACC) by combining high safety standards and greater administrative certainty, in line with European standards.

In the Italian electricity system, the price signals that should guide investment and dispatching decisions originate from the day-ahead market (MGP) and are articulated through prices that vary according to zone.

However, their ability to provide stable and 'bankable' indications over the long term is structurally limited.

2024 saw a return to average levels of the Single National Price (PUN), but the margin signal remains unstable; this nominal normalisation does not eliminate the fact that there are still peaks of negative prices in Europe and persistent price differentials between zones in the Italian market.

From 2025, the official reference for the market is the PUN Index GME, calculated as the average of zone prices weighted by the quantities actually purchased. This new metric is certainly more in line with the physical reality of the system, but it does not resolve the cause of volatility; on the contrary, it makes it more visible.

For an investor in a capital-intensive technology such as nuclear power, where the return on investment horizon is decades long, the annual average PUN is of little relevance. What matters is the distribution of hourly prices and the risk of extreme 'tails', i.e. very high or very low prices that occur today, which are directly reflected in the premiums required for financial hedging and, ultimately, in the cost of capital.

The structure of Italian forward markets accentuates this critical issue. As documented by ARERA, the standardised forward market has low liquidity, which means that most risk management takes place through non-standard bilateral contracts, with less transparency and depth. When spot market volatility extends across hedging maturities, *capital-intensive* projects pay a higher risk premium, making them more difficult to finance.

The lesson learned from the energy crisis of 2021-2023 and the subsequent reform of the European electricity market design shows us that *spot* markets alone are not capable of supporting the investments needed for the transition.

Instead, it is long-term contracts, such as Power Purchase Agreements (PPAs) and revenue stabilisation schemes (which will be analysed in more detail in Chapter 4), that will provide the financial infrastructure necessary for the market to function even for technologies with high fixed costs and low variable costs (such as nuclear power).

For Italy, where the marginal price is often determined by gas and the differentials between zones reflect network constraints and bottlenecks, well-designed long-term contracts would allow to transfer part of the price and volatility risk to the players best equipped to manage it (the state and large consumers), leaving the spot market to play its role of short-term optimisation.

This is a precondition for mobilising capital towards low-emission programmable capacity, without which the discussion on technologies and costs remains purely academic and theoretical.

3.4 European alignment financial instruments and the 2025–2030 roadmap

In recent years, Europe has rediscovered the strategic role of nuclear energy for energy security and industrial competitiveness, and Italy's nuclear strategy is part of this. Italy's inclusion in this EU framework is essential because it defines its position within the EU's drive towards 'open strategic autonomy' and provides political legitimacy and access to adequate financial instruments (European Council, 2024).

By aligning itself with these initiatives, Italy is not simply reactivating a domestic energy source; it is consolidating its role in a geopolitical bloc that seeks to reduce its dependence on external actors, historically Russia for gas and, in the future, China for clean technologies, as can be deduced from their investments (solar panels, wind power).

Politically, the most significant step was Italy's formal accession to the European Nuclear Alliance (ENA) in June 2025 (European Council, 2025). This transition from observer to full member sends a signal to investors and industrial partners of stable political commitment, thereby reducing regulatory uncertainty. The ENA acts as a coordination body between pro-nuclear Member States, with the aim of speeding up state aid procedures and activating appropriate financial instruments, particularly for new SMRs and AMRs.

At the level of European public finance, instruments such as InvestEU, mainly channelled through the European Investment Bank (EIB), offer guarantees and *blending* mechanisms to de-risk private investment in sustainable infrastructure (European Commission, 2023).

Recent experience shows a selective approach in which the EIB tends to finance more readily activities in the fuel supply chain and cycle, considered strategic for security of supply, rather than new generation capacity.

The €400 million loan granted to Orano (a French multinational) for the expansion of the Tricastin enrichment site is a precedent to consider (EIB, 2024) because it demonstrates that the nuclear supply chain and fuel cycle are 'bankable' for the EIB, provided that projects are aligned with the EU's strategic autonomy objectives, such as reducing dependence on Russian enrichment.

For Italy, this analysis suggests the adoption of a 'portfolio strategy', combining the use of different financial instruments to maximise impact.

To finance the reconstruction and development of the national supply chain, it is necessary to use the support of European institutions such as InvestEU and the European Investment Bank (EIB), while specific plans for revenue stabilisation are reserved for energy generation. Thanks to this strategic differentiation, it would be possible to meet two distinct needs: supporting the supply chain with long-term financing on the one hand, and on the other, making investments in new energy production plants more predictable and attractive to investors by reducing their risk. The Strategic Technologies for Europe Platform (STEP) is a valuable tool: a platform that aims to reallocate and boost EU funds towards strategic technologies (European Commission, 2024).

STEP does not create an ad hoc nuclear fund, but acts as a 'multiplier', enabling the financing of projects related to the supply chain, skills and 'test beds', provided that they are based on existing instruments (such as Horizon Europe or the Innovation Fund) and meet sustainability criteria.

Its aim is to ensure that Europe maintains its technological leadership, avoiding dangerous strategic dependencies in the future.

The sustainability framework, defined by the EU Taxonomy, remains an enabling constraint. The inclusion of nuclear power among 'transitional' activities, albeit with stringent conditions on safety and waste management, provides a common language for investors (European Commission, 2023). For a project, being 'aligned with the Taxonomy' does not guarantee funding, but it does become a precondition, as it influences transparency obligations (SFDR) and the *due diligence* criteria of financial intermediaries.

Therefore, the ENA, InvestEU/EIB and STEP do not replace or overlap with national choices, but rather determine their degree of financial and strategic credibility, acting as enablers.

Membership of the Alliance already reduces political uncertainty in the context of a cohesive European bloc; InvestEU and the EIB provide de-risking levers for the supply chain, in line with the objective of strategic autonomy; STEP creates a 'portfolio effect' on key technologies for the future.

The combination of these instruments, if coordinated with Italian law and future stabilisation mechanisms, has a very concrete objective: to reduce costs and accelerate the construction of the new nuclear supply chain.

Adopting this approach would allow Italy to emerge as a major player in Europe's energy and industrial policy. Italy would not only acquire the necessary technologies, but would implement them efficiently and economically, becoming a model for the entire continent.

A recent strategic study presented by Confindustria and ENEA outlines a clear path for the future of nuclear power in Italy. The following section, entitled 'Roadmap 2025–2030: the Implementation Site', details the phases and objectives.

The 2025–2030 timeframe represents a crucial phase for Italy in terms of implementing its strategic choices. This roadmap can also be seen as a series of tests for the country's political and administrative capacity. It is a matter of building an integrated agenda that addresses the risk of execution at every stage, combining governance, licensing capacity, contractual instruments, industrial preparation and social consensus, with a single underlying objective: to reduce the cost of capital and uncertainty in order to make projects bankable.

The two-year period 2025-2026 will be one of 'institutional readiness', a phase dedicated to building a solid and predictable regulatory and contractual framework. The primary objective is to reduce regulatory and political risk, making investments bankable. Leveraging the enabling law (Italian Government, 2025) in line with the EU electricity market reform (European Commission, 2023), the priority will be to translate political will into administrative certainty. This means issuing the necessary implementing decrees and, above all, establishing a one-stop shop for authorisations that offers clear procedures and binding timelines to eliminate uncertainties. A set of contractual instruments will need to be aligned at national level.

This involves defining an Italian model of two-way Contracts for Difference (CfDs), designed for low-emission capacity, and creating a guarantee vehicle to give solidity to long-term purchase agreements (PPAs). At this stage, the National Platform for Sustainable Nuclear Energy (PNNS) will have to transform its role, evolving from a consultative platform to a fully-fledged operational control room, called upon to produce measurable results on key issues such as standardisation and, where relevant, site location (PNNS, 2025).Once the regulatory framework has been established, the three-year period 2026-2028 will shift the focus from paper to construction sites, ushering in the 'industrial construction' phase. The objective here is twofold: to translate strategic planning into operational preparation and, at the same time, to establish a strong national supply chain, addressing industrial and logistical risks.

It is at this point that the abstract becomes concrete, through the selection of preferred sites, the completion of strategic environmental assessments and the opening of the first competitive auctions for *clean-firm* capacity through Contracts for Difference. In this phase, tools such as the National Platform for Sustainable Nuclear Energy (PNNS), now in operation, and the strategic use of Projects of Common European Interest (IPCEI) will be fundamental. They will act as drivers to launch, in parallel, human capital training and supply chain qualification programmes, following the trajectory indicated by Confindustria and ENEA (Confindustria-ENEA, 2025). Finally, the two-year period 2029-2030 will mark the transition from planning to implementation, representing the ultimate test for the programme's delivery.

The focus will shift to the physical implementation of the projects and the consolidation of the credibility of the entire strategy, through both execution and financial risk management. It will be at this stage that commitments will materialise, with the finalisation of the first long-term contracts that will unlock the start of construction sites for demonstration plants. Alongside these actions, a definitive alignment on the path of the National Waste Repository will become a condition that can no longer be postponed for the credibility of the entire programme.

During this period, the effectiveness of European financial instruments such as InvestEU/EIB (European Commission, 2023) and the full operation of the National Programme for Radioactive Waste Management (MASE, 2025) will not be mere supports, but decisive levers.

This phase, more than any other, will test whether the authorities have fully learned the lessons of the energy crisis: the transition from a logic of 'ex post' emergency interventions to one of 'ex ante' strategic stabilisation, implemented through contracts, market rules and forward-looking network planning.

The 2025-2030 roadmap is a veritable institutional and industrial construction site that must be built on five pillars during the same period: implementing regulations and authorisation capacity; long-term contracts aligned with EU reform; network planning and flexibility; supply chain and human capital; and a solid European anchor.

It is the only trajectory compatible with the PNIEC (MASE, 2024) diagnosis on the need for zero-emission programmable capacity and with the EU approach (European Commission, 2023), which sees revenue stability as the most effective tool for accelerating the necessary and incisive investments.

Chapter 4: Designing nuclear bankability in Europe and Italy

4.1 From sustainable-finance rules to bankability criteria

This chapter seeks to understand the concrete mechanisms that make a nuclear project financially sustainable or bankable.

The central thesis of this chapter is that nuclear investability is not a spontaneous market condition, but the result of a deliberately designed institutional, financial and regulatory architecture. This sophisticated, multi-level architecture is built to identify, allocate and mitigate specific risks that private markets alone are unable to price or absorb.

The following analysis aims to identify this structure, starting from the European sustainable finance framework, then examining public de-risking instruments at EU and international level, and finally analysing the national instruments and contractual mechanisms that ultimately determine the finance readiness.

The European sustainable finance architecture was created with the primary objective of directing private capital towards activities that make a demonstrable and measurable contribution to climate objectives, reducing the risk of *greenwashing* (European Commission, 2022; Regulation (EU) 2019/2088).

To understand its impact on the bankability of a particular and controversial asset such as nuclear power, it is necessary to analyse this system by 'dissecting' the functioning and integration of certain European mechanisms such as Taxonomy, the Sustainable Finance Disclosure Regulation (SFDR) and the Corporate Sustainability Reporting Directive (CSRD).

The mechanism, as conceptualised by the European Commission itself, is sequential and aims to create a consistent and verifiable flow of data from the corporate to the financial world (European Commission, 2024).

At its core is Taxonomy, which establishes assessment criteria to determine when an economic activity can be considered 'sustainable' from an environmental point of view (European Commission, 2022). These criteria are not generic and vaguely defined but set quantitative performance thresholds and require compliance with the 'do no significant harm' (DNSH) principle for other environmental objectives (BASE, 2021).

The second link in the chain is corporate reporting, governed by the CSRD. This directive requires many large companies to report on their sustainability performance, including the percentage of their revenues (turnover), capital expenditure (Capex) and operating expenditure (Opex) aligned with the Taxonomy criteria (European Commission, 2022). Following these guidelines, the technical criteria of the Taxonomy are translated into standardised and publicly available Key Performance Indicators (KPIs), providing the market with raw data on companies' performance in meeting environmental criteria.

The third and final link is the SFDR, which is aimed at financial market participants (asset managers, pension funds, insurance companies). This regulation requires them to be transparent about how they integrate sustainability risks into their investment decisions and, above all, to explain the extent to which financial products labelled as 'sustainable' (e.g. Article 8 or Article 9 funds) invest in economic activities aligned with the Taxonomy (Regulation (EU) 2019/2088).

This architecture seeks to create a body of evidence to enable investors to verify the consistency between the sustainability claims of a financial product and the actual performance of the companies in which it invests. The strength of the system lies in having created a common language and a set of standard metrics.

At the same time, it must be recognised that there are gaps when it comes to translating this language into quality data that is timely and truly usable in the decision-making processes of investment committees (D'Eri & Novembre, 2022). The most recent regulatory trajectory, which aims to make the framework 'more usable' through simplifications and clarifications, is a recognition of this operational challenge (European Commission, 2024).

At first glance, the Taxonomy/SFDR framework does not offer any direct financial support or public guarantees. Its contribution to financeability is more subtle but no less crucial: it acts as a *soft de-risking* tool (*Pelton et al., 2017*), mitigating a specific category of risk that increasingly weighs on investment decisions: *reputational and greenwashing risk*. The concept of *soft de-risking,* borrowed from complex project management, refers to the mitigation of non-directly financial risks such as those related to reputation or information uncertainty, which nevertheless improve the overall context of an investment, unlike *hard de-risking* tools that directly affect the project's cash flows (Pelton et al., 2017).

In a context that lacks standardised definitions, any investment in a controversial sector such as nuclear power would expose a financier to reputational uncertainty that is difficult to price. Accusations of *greenwashing* or allegations about the real sustainability of the asset would translate into a higher risk premium, i.e. a higher cost of capital. Instead, by creating a definition of 'sustainability' based on scientific criteria and a formal legislative process, the Taxonomy provides a defensible basis for investment decisions (European Commission, 2022).

The bankability of a nuclear project in the European context depends not only on its technical alignment with the Taxonomy criteria, but critically on *the quality and traceability of data* throughout the entire information chain.

If a project promoter provides incomplete, opaque or low-quality data on its taxonomy KPIs, it reintroduces into the system the information asymmetry that the framework was designed to eliminate.

For a financier, this uncertainty translates directly into a cost: higher debt spreads, more onerous guarantees or, in the worst case, the abandonment of the investment (Becker et al., 2022). Transparency and robustness of reporting are now a fundamental parameter of credit risk and no longer an optional extra of *corporate social responsibility*.

At the heart of the debate on the inclusion of nuclear power in the Taxonomy was the principle of 'do no significant harm' (DNSH) (BASE, 2021). The Commission's Joint Research Centre (JRC) analysis concluded that there is no scientific evidence that nuclear energy causes greater harm to human health

or the environment than other electricity generation technologies already included in the Taxonomy, such as renewables (Joint Research Centre, 2021). This conclusion was the technical basis for the inclusion of nuclear energy in the 2022 Complementary Delegated Act (European Commission, 2022). This technical conclusion is strongly supported by internationally consolidated data on the health impacts of the entire life cycle of different energy sources. Comparative studies, such as those aggregated by Our World in Data (based in turn on analyses published in scientific journals such as *The Lancet)*, show that nuclear energy, with a mortality rate of around 0.03 deaths per terawatt hour (TWh), has one of the lowest impacts overall.
This value is directly comparable to that of solar (0.02 deaths per TWh) and wind (0.04 deaths per TWh) and is almost a thousand times lower than that of coal, which causes approximately 24.6 deaths per TWh for the same amount of energy produced, mainly due to the impact of air pollution.

Returning to the concept of DNSH, a significant part of the critical literature and some Member States have challenged this approach, not so much by questioning the data, but rather the logical equivalence between the statement 'no worse than' and the principle of 'no significant harm' (BASE, 2021). Criticism has focused on the alleged inadequacy of the metrics used to assess low-probability, high-impact incidents (the concept of *'tail* risks') and the very long-term management of radioactive waste (BASE, 2021).

From a project-level creditworthness perspective, this scientific and political controversy has a clear operational implication: it does not rule out the financeability of nuclear power, but *it raises the bar for the evidence required during due diligence*.

DNSH ceases to be a simple 'box to tick' and becomes an area of in-depth risk analysis. Lenders are prompted to require promoters to provide more robust evidence on plant safety, waste management plans and minimum safeguards. This translates into the need to include more stringent compliance and monitoring clauses in prospectuses and financing agreements, both *ex ante* and *ex post,* to monitor the most controversial risk profiles, with increased costs and longer timelines. (BASE, 2021).

The integrity of this complex system is ensured by an increasingly vigilant level of institutional supervision.

The European Securities and Markets Authority (ESMA) has taken a decisive step by integrating environmental risks into its ordinary scope of analysis. Starting in 2022, its *Risk Dashboard* will consider them as a separate category of vulnerability for European capital markets, identifying three threats: sudden changes in investor *sentiment* on climate issues; *greenwashing;* physical risks linked to extreme events (ESMA, 2022). This move signals that the quality and reliability of ESG data have become a matter of financial stability and investor protection, directly influencing the *due diligence* that asset managers must conduct.

At the same time, the Commission has addressed the issue of ESG rating management, which is characterised by unclear methodologies and often divergent results. The proposal to regulate ESG rating providers aims to impose transparency and subject them to supervision, with the aim of reducing unjustified dispersion in judgements and making ratings effectively useful and reliable (*decision-useful)* tools for asset managers (European Parliament, 2024).

For investors, this means being able to rely on more robust external assessments, reducing opacity from the outset and, consequently, the reputational risk premium associated with relying on poorly defined sustainability metrics.

The recent regulatory trajectory (greater usability of the framework, supervision of ratings, integration of environmental risks into financial supervision) is moving towards making the language of sustainable finance more understandable for potential investors. For nuclear power, this means that the question is no longer 'whether' it can fall within this scope, but 'how' to structure its projects, contracts and finance so that regulatory requirements become measurable credit parameters rather than administrative obstacles (European Parliament, 2024).

4.2 EU financing tools within a selective technology-neutral regime

The portfolio of instruments that the European Union has made available to finance industrial transition and decarbonisation takes a more 'horizontal' than sectoral approach.

In theory, these instruments are technologically neutral: they enable supply chains and technologies considered strategic for the Green Deal objectives, but leave it to specific implementation schemes, such as calls for proposals, eligibility criteria and guarantees, to decide which projects actually access the funds (European Commission, 2025). This approach was further consolidated with the 2025 *Clean Industrial Deal* implementation package, which introduced a new framework for state aid (*Clean Industrial Deal State Aid Framework,* or CISAF) and strengthened synergies with existing programmes such as the Innovation Fund and InvestEU (European Commission, 2025).

For the nuclear sector, this means that access to EU funding is not precluded, but is conditional on a project's ability to demonstrate its added value in environmental, industrial and safety terms, passing the selective filters of each instrument. After analysing how the European framework for sustainable finance acts as a tool for *'soft de-risking'*, primarily mitigating reputational risk through common standards, the analysis now shifts to the more direct public instruments that the Union has introduced.

The EU's approach is technologically neutral; however, a detailed analysis of each instrument reveals that access for the nuclear sector is not easily guaranteed. Rather, it is conditional on the ability of individual projects to pass selective filters and demonstrate specific added value in terms of the environment, industry and strategic security.

The European Union has structured many instruments to accelerate the transition, but for the nuclear sector, access to these resources is not as straightforward as it is for other more widely used types of energy. Take, for example, the Innovation Fund, the EU channel designed to support innovative low-emission technologies with strong CO2 reduction potential. Looking at the projects funded so far, a very clear trajectory emerges: the fund has systematically favoured small-scale projects in sectors such as renewable manufacturing, building materials, storage and hydrogen. There is no sign of nuclear power generation projects at this stage. Although there is no formal ban, this de facto signal suggests a preference for other technologies, probably because the fund focuses on the additionality of innovation. For a nuclear project based on mature technologies, demonstrating that it is sufficiently innovative compared to the state of the art is a complex undertaking. So, while there may be opportunities for specific components, advanced fuels or support solutions, the Innovation Fund does not currently appear to be the most likely channel for financing large generation plants.

InvestEU operates on a different logic, providing no direct grants but acting as a financial *de-risking* tool. Its aim is to mobilise private capital by offering an EU budget guarantee, usually through implementing partners such as the European Investment Bank (EIB). Its role is therefore crucial in lowering the cost of capital for projects that the market considers too risky. The 2025 *Clean Industrial Deal* communication also announced new financial products under the InvestEU umbrella to support long-term power purchase agreements (PPAs) and critical manufacturing supply chains. Here too, however, the relevance for nuclear power concerns the *enabling industrial supply chain* rather than the construction of new reactors. Effective access remains subject to credit discretion and the rigorous climate alignment test required by the EIB.

Completing the picture of instruments is the Strategic Technologies for Europe Platform (STEP). This is not a new fund, but a *multiplier* and quality assurance mechanism. Its purpose is to reallocate and leverage existing resources from other programmes (such as the Innovation Fund and InvestEU) with additional funding for strategic projects, which are given a 'seal of sovereignty'. It should be noted that the priority technologies listed in the 'clean' cluster include renewables, storage, networks and hydrogen, but do not explicitly mention nuclear. As a result, access to STEP for a nuclear project is a remote possibility, entirely dependent on its ability to qualify through the programmes mentioned below and to demonstrate an exceptional contribution to European industrial sovereignty. Once again, this is a more realistic scenario for industrial components and technologies related to the fuel cycle that are needed for new generation.

The most emblematic case for understanding the current position of European financial institutions is the €400 million loan granted by the EIB in 2025 to Orano for the extension of its uranium enrichment site in Tricastin, France (European Investment Bank, 2025). This project, which will increase capacity by more than 30% through new-generation centrifuges, passed the EIB's filters for three fundamental reasons, which reveal the bank's underlying logic.

First and foremost is consistency with security of supply: the project fiche explicitly justifies the investment on the basis of its contribution to the EU's objectives of nuclear fuel diversification and strategic autonomy, reducing dependence on external suppliers, particularly Russia. The second reason lies in a robust environmental and social assessment: approval was subject to rigorous scrutiny based on an environmental impact assessment (EIA), public consultations and detailed waste management plans. Finally, its climate alignment was assessed, with the project being judged to be in line with the objectives of the Paris Agreement and classified as 'low-carbon energy' according to the EIB's *Climate Bank Roadmap*, the guiding document for all the bank's investments (European Investment Bank, 2020).

This precedent is crucial because it documents the accessibility of *the nuclear supply chain* to EIB and InvestEU capital. However, it also reveals a fundamental distinction. The financing in Orano mitigates a *systemic and geopolitical risk* for the entire European Union, namely the vulnerability of the fuel supply chain on which dozens of operating reactors depend. It is, in fact, an investment in the resilience of the entire European nuclear fleet. In contrast, financing the construction of a new power reactor in a single Member State represents a much higher and more concentrated project risk (construction, market and regulatory risk) with benefits perceived as primarily national. The hierarchy that emerges is clear: the EIB is willing to use its budget to address strategic vulnerabilities at European level (as in the case of Orano), but leaves the more risky and politically complex task of financing new generation capacity to national actors. The latter can, and must, use European enabling frameworks, such as the aforementioned CISAF, to design their own support schemes; at the same time, they cannot expect the Brussels institutions to take their place in covering the risk of *first-of-a-kind* projects (European Investment Bank, 2025; Sfen, 2025).

4.3 De-risking models from the United States and the United Kingdom for Italy's financing architecture

While Europe is defining an enabling framework but leaving the burden of direct de-risking to Member States, other advanced economies have developed more proactive models to make nuclear power attractive to investors again. A comparative analysis of the strategies adopted by the United States and the United Kingdom serves as an example, as, while sharing the objective of attracting private capital, they are based on profoundly different risk allocation logics. These models offer a set of options that could be replicated and whose principles can inform the design of effective instruments in the European context.

In the United States, the cornerstone of federal support is the *Loan Programmes Office* (LPO) of the Department of Energy (DOE). The LPO's approach is not to replace the market, but to catalyse it by absorbing specific, high-impact risk that the private sector is unwilling to finance on acceptable terms. This typically involves the technological risk associated with *first-of-a-kind* (FOAK) projects or, as in the emblematic case of the Palisades plant in Michigan, *restart risk* (Department of Energy, 2024).

The Palisades case is indicative of the LPO's *modus operandi*. The DOE has provided a guarantee on a loan of up to $1.52 billion to finance the first restart of a commercial reactor already in the process of being decommissioned in the United States (Department of Energy, 2024). The crucial point is not only the amount of support, but its structure: the financing is not a blank cheque, but is disbursed in *successive tranches,* conditional on the achievement of *verifiable milestones.* DOE press releases document this progression: a disbursement in March 2025, followed by others in April, June and August, each linked to measurable progress in the authorisation process at the *Nuclear Regulatory Commission (*NRC) and in preparatory activities (Department of Energy, 2024).

This financial engineering has two powerful effects. First, it internalises the most opaque risk phases (authorisation, supply chain, technical) that commercial banks would not be able to price, leaving the promoter responsible for operational performance once the plant is restarted. In essence, the state 'buys' a temporary and specific risk to make the overall profile of the project acceptable to the market (Department of Energy, 2024). Second, the tranche structure and public communication of releases make the support *politically defensible and justifiable* because public spending is linked to concrete progress and the mechanism is reversible in the event of regulatory failure, mitigating accusations of indiscriminate *'bailouts'* (Department of Energy, 2024).

The UK is pursuing a different path, not fiscal but regulatory, through the *Regulated Asset Base* (RAB) model, applied to the Sizewell C project. Here, the main lever is not a public guarantee on a loan, but *ex ante* regulation of the project's revenue stream, which is 'regulated' and guaranteed throughout its entire life cycle, including the construction phase.

The core of the RAB model is the transformation of an electricity generation project, which by its nature is exposed to market risk and rising costs during construction, into an asset similar to a regulated network infrastructure, such as a gas pipeline or power line. During the long construction phase, when the plant is not generating revenue, the project is entitled to receive a cash flow, called *Allowed Revenue,* financed by a small levy on the bills of all electricity consumers. This mechanism transfers a significant portion of the construction risk and cost of capital from the project promoters to a regulated and broad base, which will then benefit consumers, thereby also drastically reducing the WACC.

The legitimacy of this risk transfer is based on a sophisticated and transparent governance architecture. An independent regulatory authority, Ofgem, is responsible for defining the parameters of the financial model (*Price Control Financial Model*), approving eligible costs and monitoring performance. The *Low Carbon Contracts Company* is the body responsible for collecting payments from energy suppliers and disbursing them to the project (Low Carbon Contracts Company, n.d.). Transparency in all calculations and reporting is essential to maintaining operator discipline and public acceptance of the model (Ofgem, 2025).

The choice between the US and UK models reflects two different 'social contracts' on who should bear the financial risk of a large energy project. The US model places the risk on *the public budget* through a *'contingent liability*'. This means that the state acts as guarantor for the project. This is not an immediate expense, but a *potential risk:* if the project were to fail and be unable to repay its debts, the state budget would have to cover the losses. This choice is justified on the basis of a higher national interest, such as energy security or decarbonisation. The British model socialises the risk in a different way, placing the direct cost on *the energy consumer.* Instead of a future and uncertain risk for the state coffers, a small but certain levy is introduced on energy bills, starting from the construction phase. This cost, spread across millions of users, is justified not by an appeal to the national interest, but by the transparency of a regulatory process that defines and supervises it.

If the primary constraint is public debt, a model such as the British RAB model may be more attractive. If, on the other hand, the main constraint is the impact on bills and the social acceptability of an advance levy, an LPO model, which uses public guarantees to mobilise private capital, becomes a more viable and accepted option.

As Italy restarts its journey towards nuclear power, it finds itself having to build from scratch a structure for bankability that is robust, credible and fits into the European system. The strategy that is emerging does not rely on a single decisive instrument, but on an integrated approach that combines three fundamental pillars: regulatory certainty, compatibility with European rules on state aid and the mobilisation of public development finance as a catalyst for private capital. The success of this strategy will depend not so much on the quality of the individual elements as on their coherent interconnection. There are three essential factors on which any type of project may depend.

First and foremost, legal and regulatory certainty, which is currently enshrined in the enabling law. The first pillar is the establishment of a predictable legislative and authorisation framework. The enabling law on 'sustainable nuclear power' aims to fill the regulatory void created after 2011 with Fukushima, defining competences, procedures and a single authorisation for the entire life cycle of the plants. The aim of this measure is to reduce the *regulatory risk premium,* one of the most costly components of the cost of capital. Uncertain timelines and slow procedures are a lethal deterrent to investments with decades-long horizons. The proposal for a two-stage authorisation *roadmap*, standardisation of the reference project and authorisation for siting, and the prior involvement of the Unified State-Regions Conference are crucial steps in reducing the risk of litigation and delays *ex ante*, as highlighted in the Confindustria-ENEA report (Confindustria and ENEA, 2025).

The second factor is compatibility with State Aid (CISAF), which is linked to the importance of aligning with European rules. The *Clean Industrial Deal State Aid Framework* (CISAF) provides the most pragmatic and up-to-date channel for designing national de-risking schemes that are compatible with the internal market. The CISAF imposes strict discipline: following the principle of additionality, aid must be limited to the minimum necessary to unlock investment; support must be proportionate (giving preference to competitive tendering procedures for allocation) and must include *claw-back* mechanisms to avoid overcompensation if the project generates extra returns. For Italy, this means that any support instrument, such as forms of revenue stabilisation, must be designed in a competitive manner and notified to the Commission, arguing its necessity for decarbonisation objectives and industrial importance (European Commission, 2025).

The final pillar is the anchor of public finance (CDP): Cassa Depositi e Prestiti (CDP), through its *Green, Social and Sustainability Bond Framework*, already has instruments aligned with market principles to issue thematic debt and channel resources towards projects with verifiable environmental and social impacts (Cassa Depositi e Prestiti, 2023). In the nuclear context, its potential role is not to replace private capital, but to act as *an anchor investor* or guarantor. It can provide patient capital in the early, riskier stages of a *first-of-a-kind* project, or structure guarantees that make the project's risk profile acceptable to commercial banks and institutional investors. Its ability to engage with European counterparts (EIB, InvestEU) is key to giving financial depth to a programme that requires an unprecedented scale of investment (Cassa Depositi e Prestiti, 2025).

While the three pillars provide the framework, a crucial element of the architecture is still in the design phase: the *long-term revenue stabilisation mechanism*. *Energy-only* electricity markets, in which operators are remunerated only on the basis of the energy actually sold and based on spot prices, do not provide sufficiently stable price signals to remunerate highly capital-intensive investments with low operating costs such as nuclear power. The absence of a dedicated instrument to guarantee the stability of future revenues increases the perception of risk for investors. This uncertainty translates directly into a higher cost of capital (WACC), as financiers demand a higher premium for the risk they assume. However, by increasing financing costs, the final levelised cost of energy (LCOE) also increases, making the project less competitive than less risky alternatives.

The MASE decree of June 2025 on long-term PPAs focuses on renewable sources and does not offer a direct channel for nuclear projects (MASE, 2025). There is therefore a need to consider an alternative solution. The most likely options are *two-way contracts for difference (CfDs),* awarded through competitive auctions, or capacity remuneration schemes, both to be structured in accordance with the CISAF target models (European Commission, 2025). The political choice will be between a technologically neutral scheme, open to all programmable zero-emission capacity, and one specific to nuclear power. In both cases, the quality of the design and the speed of the notification process in Brussels will be the determining factors for approval times and investor confidence.

The logic behind the Italian strategy can be described as an exercise in '*risk unbundling*'. Rather than addressing 'project risk' as a monolithic and difficult block, the approach consists of breaking it down into its fundamental components, assigning each one the most appropriate mitigation tool. Regulatory and authorisation risk is addressed by the 2025 enabling act on sustainable nuclear energy, which aims to establish clear, predictable procedures and expedited timelines—consistent with the approach outlined by the National Platform for Sustainable Nuclear Energy (MASE, 2024). *Construction risk,* the most 'feared' by private investors, can be mitigated by public guarantees structured by Cassa Depositi e Prestiti (CDP) and the Treasury, based on the US Loan Programs Office (LPO) model, to ensure the 'bankability' of projects (Cassa Depositi e Prestiti, 2024). Finally, *market and price risk* is neutralised by a long-term revenue stabilisation mechanism, such as a Contract for Difference (CfD), designed in accordance with the rules of the European Clean Industrial Deal State Aid Framework (CISAF) to ensure a stable economic return.

The success of Italy's nuclear programme will depend on the effective, consistent and synchronised combination of all these elements. A solid legal framework will not attract capital without a credible long-term contract; a well-designed contract will be useless if regulatory uncertainties persist; and none of these instruments will work without a public financial player capable of anchoring the initial investments. Only consistent implementation along these three lines can transform a technological possibility into bankable projects.

4.4 Multilateral finance, governance standards and system-value metrics in nuclear bankability

The investability of nuclear power depends on national architectures, but it is deeply influenced by large public financial institutions, whose orientation sends signals to private markets. The European Investment Bank (EIB) and the World Bank, together with technical bodies such as the Nuclear Energy Agency (NEA), are gradually moving away from a binary approach of either financing or not financing, towards a more sophisticated perspective that links access to capital to bankability pathways conditioned on the quality of governance, industrial maturity and rigorous impact assessment.

The EIB, which has described itself as the EU's 'Climate Bank', has made all its new operations fully aligned with the objectives of the Paris Agreement. This commitment has translated into a rigorous lending selection methodology, outlined in its *Climate Bank Roadmap* and *Energy Lending Policy,* in which taxonomy, the DNSH principle and carbon shadow prices are not rhetorical references but operational selection and *due diligence* criteria (European Investment Bank, 2020; European Investment Bank, 2019).

Two elements in particular define the EIB's approach to 'translating' climate impact into an internal financial cost for projects. The first tool used is the shadow carbon price. This value does not constitute a direct monetary outlay, such as a tax, but rather a cost that is charged for each tonne of

CO_2 equivalent that a project is estimated to emit over its operational life. The key feature of this tool is its *dynamic and increasing trajectory,* with a target value of *€800/tCO2e* by 2050. This progression acts as an economic signal, reflecting the increase in the social and economic cost attributed to emissions in the long term. The impact of this mechanism on cost-benefit analysis is substantial. By including this prospective cost in its assessment models, the EIB *internalises the negative externality* of greenhouse gas emissions. As a result, a carbon-intensive project sees its expected profitability reduced and its financial risk profile increased due to this latent economic liability. On the other hand, zero- or low-carbon technologies are inherently more competitive and financially sound, as they are free from this burden. The EIB's strategy promotes environmental sustainability by redefining the parameters of economic viability, demonstrating that decarbonisation is not a constraint but a source of *economic value* and a fundamental prerequisite for the stability and profitability of future investments.

In addition to the price of carbon, the EIB's lending policy in the energy sector places the eligibility of projects in the 'renewable and low-carbon' category, provided that they comply with internal emissions standards and pass the bank's environmental and social screening, which explicitly incorporates the DNSH principle (European Investment Bank, 2019). This formulation, based on principles rather than lists of technologies, avoids making abstract statements about nuclear power and leaves the decision to the test of facts. A nuclear project that robustly demonstrates its net climate benefits, safe waste management and compliance with environmental and social safeguards may fall within the scope of potential financeability. The downside of this approach is that it maintains very high standards, creating space above all for supply chain components, innovation and modernisation; for the new generation *tout court*, the test remains the ability to demonstrate climate additionality and risk management that exceed the EIB's rigorous thresholds, which is very difficult.

Looking at the global picture, a significant change of phase was marked by the memorandum of understanding signed between the World Bank Group and the International Atomic Energy Agency (IAEA) in June 2025. This agreement marks the first cautious formal return of the World Bank to the nuclear sector after decades of absence. The choice of areas of cooperation is strategic and aims to reduce controversy by focusing on three lines of work.

These include strengthening regulatory and safety knowledge in supporting emerging countries to build competent and independent regulatory institutions. It also supports the extension of the life of existing plants by recognising LTOs as one of the most cost-effective levers of decarbonisation available. It also provides leverage for accelerating SMRs: considering small modular reactors as a flexible, low-emission generation option suitable for smaller grids and with lower initial capital expenditure for middle-income countries.

The significance of this agreement is more political than financial. It does not mean that the World Bank will directly finance new power plants in Europe, but it sends a powerful signal of legitimacy to the sector (World Bank Group and IAEA, 2025). It reduces perceived political uncertainty globally and may reopen channels for co-financing (*blending)* and guarantees with other multilateral development banks that are currently effectively closed. For private finance, this signal reduces the political risk associated with the sector, making it a more conventional option in infrastructure investment portfolios.

The latest studies by the Nuclear Energy Agency (NEA), based on the analysis of concrete cases, bring the debate on financeability back to issues of governance and execution. We find three fundamental lessons.

The first is that the real Achilles' heel is construction risk. For *first-of-a-kind* projects and in contexts with immature supply chains, it is not enough to mitigate price risk with instruments such as CfDs or PPAs. Private capital will not come at acceptable costs if a significant portion of the execution risk (delays and cost overruns) is not socialised. Hence the interest in models such as RAB or CWIP (*Construction Work in Progress)*, which include ongoing costs in the tariff, distributing the risk between consumers and taxpayers and reducing the WACC (Nuclear Energy Agency, 2024).

The second lesson is that governance matters more than the ideology of public versus private financing. A comparative analysis of financing models shows that, regardless of the structure chosen, the risks ultimately fall on the community. What must be understood is that either the construction phase is controlled with aligned incentives, clear *milestones* and stringent contractual responsibilities throughout the *supply chain,* or any financial scheme degenerates into an inefficient transfer of costs. The maturity of the technology, seriality and quality of project management are more decisive than the abstract debate between public or market intervention.

The final lesson is that market design reform is now necessary. Electricity markets based solely on the marginal price of energy (*energy-only*) are unable to provide the price signals needed to remunerate long-term, capital-intensive investments. Market design reform is the institutional prerequisite for the effectiveness of financing instruments.

All these elements suggest that the role of public financial institutions is not to decide 'whether' to finance nuclear power, but to build effectively bankable routes that combine climate criteria with performance-based de-risking instruments. Any project that is poorly structured or has fragile governance or supply chains will have no financial framework to bridge the gap.

The analysis conducted in this chapter converges towards a fundamental conclusion: the bankability of nuclear power, and more generally of programmable low-emission technologies, requires a paradigm shift that shifts the focus from plant-level cost assessments to system-level value metrics, and translates this value into contracts and rules that make it financeable.

As already introduced in previous chapters, the technical and economic debate has moved beyond the isolated use of *Levelised Cost of Energy* (LCOE) as a benchmark metric. Although useful for comparing the average costs of programmable technologies in a traditional system, LCOE becomes misleading in an electricity system with high penetration of variable renewable sources. The evaluation must now be based on more sophisticated metrics that value the stability and efficiency of the entire system (Nuclear Energy Agency, n.d.).

These now include, for example, the 'System-LCOE', which internalises the integration costs (profile, balancing and network costs) that non-programmable sources impose on the system and which grow non-linearly with their penetration. It serves to define comparable cost thresholds between different technologies based on the real total cost to the community.

This architecture of metrics and contracts fits perfectly into the strategic diagnosis outlined in the Draghi Report on European competitiveness. The diagnosis is clear: Europe suffers from structurally higher and more volatile energy prices than its global competitors, and the fragmentation of capital markets keeps the cost of transformative investments high (Draghi, 2024). The prescription is equally clear: adopt a *technology-neutral* but *system-aware* approach*,* in which technologies are evaluated for their joint contribution to cost, security and volatility. The lever for doing so is the use of well-designed long-term contracts and network investments to anticipate the benefits of the transition, stabilise expectations and attract private capital.

But how can these massive investments be scaled up at European level without triggering harmful tax competition between states and without wasting public resources? An effective governance model can be borrowed from the lessons learned by the European Court of Auditors in its analysis of IPCEIs (Projects of Common European Interest) for batteries. The effectiveness of such instruments depends on four conditions:

1) measuring the *funding gap*: calculating the minimum public support needed for each project, avoiding generalised aid
2) including *claw-back* mechanisms: recovering excess returns to avoid overcompensation
3) making disbursements conditional on verifiable *milestones*: linking public support to tangible progress
4) linking support to industrial KPIs: independently monitoring results in terms of capacity and timing

This is the 'institutional route' necessary to make investments in *low-carbon* programmable power *truly* scalable (European Commission, 2021). In conclusion, in a Union exposed to high and volatile prices, the competitive advantage lies not in 'average cost' but in the ability to price the value of the system through contracts and rules that ultimately make it bankable.

Chapter 5: Newcleo bankability and strategic positioning in the European ecosystem

5.1 System costs within the European SMR landscape

This chapter moves from the general architecture of nuclear technologies to their concrete application, analysing the Newcleo case study.

The aim is to assess the credibility of its technological and industrial proposal, its competitive positioning in the European ecosystem of Small Modular Reactors (SMRs) and then its bankable revenue model. To do this, it is necessary to define the new competitive paradigm in which operators such as Newcleo find themselves competing.

The energy transition has shifted the focus of economic evaluation from the Levelised Cost of Energy (LCOE) metric to the more comprehensive system costs metric. In an electricity system with increasing penetration of variable renewable energy (VRE) sources such as wind and photovoltaics, LCOE, which measures the average cost per MWh produced, becomes an inadequate and often misleading metric. It ignores the additional costs that VRE impose on the system to ensure a reliable and continuous energy supply: profile costs (to cover production 'gaps' with back-up capacity), balancing costs (to manage forecast uncertainty) and network costs (to connect often remote plants and reinforce infrastructure) (NEA, 2018).

OECD-NEA literature shows that these system costs grow non-linearly with the share of VRE, becoming a dominant component of the total cost of decarbonisation (NEA, 2012). As a result, the economic value of a technology no longer lies solely in its ability to produce low-cost MWh, but in its contribution to reducing overall system costs (NEA, 2024). It is in this new context that low-emission programmable capacity (*clean firm power)*, such as that offered by nuclear power, acquires strategic value. Its ability to provide energy in a predictable and controlled manner reduces the need for expensive gas back-up plants, large-scale storage systems and massive grid investments, thereby lowering the total cost of achieving climate targets (NEA, 2019).

This evolution is not merely an academic debate; it reflects a deliberate reorientation of energy policy and market design at the European level. The emphasis of the Draghi Report on competitiveness and recent European Commission initiatives on long-term contracts such as Contracts for Difference (CfDs) or regulated models such as the *Regulated Asset Base* (RAB) is the clear recognition that the market itself must be 'engineered' to remunerate the systemic value of stability and flexibility (Draghi, 2024). The market in which Newcleo and other SMR developers will compete is not that of the past, based on marginal hourly pricing, but a newly conceived market designed to give a stable price signal to technologies that provide essential public goods such as grid adequacy and resilience.

The central thesis of this chapter is, therefore, that the competitiveness and bankability of an Advanced Modular Reactor (AMR) such as Newcleo's do not depend solely on its technological excellence, but on the consistency of its industrial strategy with this new paradigm of systemic value and its ability to fit effectively into the institutional, regulatory and financial ecosystem that Europe is building to govern the transition.

Before analysing Newcleo's proposal in detail, it is essential to outline the competitive landscape in which it operates. Within Europe, a triad of reference options based on light water SMR (LWR) technology has emerged, aiming for deployment in the 2030-2040 timeframe. Although they share the same basic promise of reducing system costs by providing programmable capacity with fractionable investments, these solutions diverge profoundly in terms of industrial model, regulatory status and bankability strategy. Their trajectories not only represent different business plans, but also reflect a microcosm of the different political and economic paradigms of nuclear development already analysed at a global level in Chapter 2.

The *Rolls-Royce SMR* embodies the UK model, which is oriented towards a state-led industrial policy. The British strategy does not merely incentivise the market, but actively shapes it through 'sovereign procurement'. The government, through the Great British Nuclear organisation, has identified Rolls-Royce SMR as the preferred bidder for the construction of a national fleet, creating a solid and predictable anchor demand. This public commitment is key to de-risking the entire industrial chain, justifying the application of financial instruments such as the *Regulated Asset Base* (RAB), which socialises the construction risk, or Contracts for Difference (CfDs), which guarantee revenue stability. On the regulatory front, the project has completed the first phase of the *Generic Design Assessment* (GDA) and has entered *Step 2,* a sign of traction that progressively reduces uncertainty and, consequently, the cost of capital (ONR, 2024). This combination of state commitment, guaranteed demand and a clear regulatory path reflects a coherent, planned industrial policy, focused on energy sovereignty and the rebuilding of domestic manufacturing capacity.

The *NUWARD* project, led by EDF, aims to become the 'European champion' of SMR-LWRs, embodying a typically EU integrationist model (World Nuclear News, 2023). Its bankability strategy is not based on a single national customer, but on the creation of a 'portable' licence valid throughout the Union. Pre-licensing work with the French authority (ASN), coordinated with European harmonisation initiatives led by ENSREG (*European Nuclear Safety Regulators Group)*, aims to create a common regulatory language that avoids costly national duplication and promotes standardisation (NUWARD, 2023). For a project targeting a continental market, the political economy of a transferable authorisation is a more powerful de-risking factor than a single contract. This strategy naturally relies on the maturity of the French industrial ecosystem and nuclear supply chain, which serves as a platform for European expansion.

Then there is the *GE Hitachi BWRX-300*, which represents a 'grid-first' model, driven by clear market demand from industry and the need to replace coal-fired generation, as demonstrated by its progress in Poland. The logic here is primarily economic and pragmatic: to reduce *time-to-market* and construction risk through a radically simplified design and maximum reuse of an existing and recognisable LWR supply chain (GE Vernova, 2025). The recent selection of the Wloclawek site for the first Polish plant formalises the transition from theory to practice, linking the project to a concrete need for stable energy for large consumers in a region where security of supply and price volatility are central issues (World Nuclear News, 2025). This approach responds to a specific economic problem: the cost and security of energy, choosing the technology best suited to solving it in the shortest possible time.

These three strategies demonstrate that even within the EU, competition on SMRs is not simply a technological race, but a comparison between different industrial policy philosophies, each of which uniquely shapes the path to financeability.

5.2 Newcleo's LFR proposition between closed fuel cycle and strategic partnerships

Unlike LWR options, which represent an evolution of mature technologies, Newcleo's proposal deliberately places itself at the frontier of innovation, focusing on a fourth-generation Advanced Modular Reactor (AMR). This choice entails an intrinsically different risk-return profile and requires a more sophisticated industrial and investeability strategy, which is not based on the maturity of the technology, but on its ability to offer unique solutions to systemic problems and to align with specific industrial and political ecosystems.

At the heart of Newcleo's proposal is a lead-cooled fast reactor (LFR). The choice of liquid lead as a coolant is the foundation of a different safety paradigm. Unlike water reactors, which operate at high pressure, 'pool' LFR reactors operate at atmospheric pressure. This eliminates the risk of accidents due to high-energy coolant leakage at source. In addition, lead has high thermal inertia (high boiling point and high heat capacity) and is chemically inert, reacting neither with air nor water. These physical properties translate into intrinsic safety characteristics: in the event of anomalies, the reactor cools passively by natural convection, ensuring a wide time window for intervention without requiring complex active safety systems. This potential for plant simplification is one of the main drivers for long-term cost reduction.

The second technological pillar is the choice of fuel cycle. The fast neutron spectrum of the LFR allows the use of Mixed Uranium and Plutonium Oxide (MOX) fuel, produced from the spent fuel of traditional reactors. This strategy transforms what has historically been perceived as the main critical issue of nuclear power, the management of long-lived waste, into a resource. Newcleo's approach proposes a closed fuel cycle, in which existing waste is 'burned' to produce new energy, drastically reducing the volume and long-term radiotoxicity of the final waste destined for geological disposal (Newcleo, 2025).

Far from being merely an environmental proposal, this choice is proving to be a move of profound strategic intelligence. It creates a symbiosis with French nuclear policy, which has been pursuing a closed-cycle strategy for decades and has the world's most mature industrial infrastructure for fuel reprocessing and MOX fabrication, concentrated in the Orano plants at La Hague and Melox. The recent €400 million loan granted by the EIB to Orano, motivated by reasons of European 'strategic autonomy', demonstrates that the fuel cycle supply chain is considered a strategic asset worthy of public financial support at EU level (EIB, 2025). By moving its headquarters to Paris, Newcleo has placed itself at the centre of this industrial and political ecosystem (Newcleo, 2024). By offering technology capable of exploiting France's plutonium stocks, the young company is positioning itself as a strategic partner for the management of a national asset, transforming a liability (spent fuel) into a resource. Alignment with French national interests and this is a powerful de-risking factor, far more solid than simple abstract technological superiority.

Aware that a *first-of-a-kind* (FOAK) project cannot be developed in isolation, Newcleo has built an industrial strategy based on a multi-level partnership, aimed at *'risk un*bundling' (a concept explained in Chapter 4) along three lines: technological de-risking, industrial de-risking and market de-risking.

On the *technological de-risking* front, Newcleo has anchored its development to two of Europe's most important nuclear research centres. The cooperation agreement with Italy's ENEA allows it to leverage the unique expertise and infrastructure of the Brasimone Centre, a global centre of excellence in lead-cooled fast reactor technology. The collaboration involves the construction of a non-nuclear electrical prototype (PRECURSOR) to study the thermodynamic and mechanical performance of the system, a fundamental step in validating the design before moving on to the nuclear phase (ENEA, 2022). Similarly, the strategic partnership with France's CEA, the alternative and atomic energy agency, covers critical areas such as fuel qualification, calculation codes and materials research, effectively placing Newcleo's development within the French technology roadmap (World Nuclear News, 2024).

For *industrial and supply chain de-risking*, the strategy focuses on risk separation and key supplier qualification. The joint venture with Nextchem, a subsidiary of the Italian Maire group, for the development and construction of the 'conventional island' and *Balance-of-Plant* (BOP), is crucial because it clearly separates the innovative and regulatory risk associated with the nuclear island (the LFR reactor) from the more conventional and manageable risk associated with civil and plant engineering (Maire, 2025). Added to this is the cooperation and investment agreement with the Tosto Group, a leader in the production of large components and pressure equipment. This partnership is fundamental to industrialising the production of the most critical components of the reactor, such as the vessel, and includes a *work-for-equity* mechanism that transforms a strategic supplier into an investor, fully aligning incentives with the success of the project (Walter Tosto S.p.A., 2023).

On the *market de-risking* front, Newcleo does not position itself as a simple electricity supplier, but as an integrated energy hub capable of creating anchor demand in diversified sectors. The higher outlet temperature of the LFR reactor makes it ideal for process heat cogeneration for *hard-to-abate* industries (Newcleo, 2025). Memoranda of understanding (MoUs) with large industrial consumers, such as steel manufacturer Danieli, are a key step in transforming this technical potential into a commercial reality (GreenSteelWorld.com, 2025). Added to this are collaborations to explore completely new applications: the agreement with Saipem to study the use of offshore reactors to decarbonise oil & gas platforms and power floating units (Saipem, 2024), and the agreement with Fincantieri and RINA for a feasibility assessment on nuclear ship propulsion (Fincantieri, 2023). The structuring of long-term *offtake* contracts for heat, steam or energy in non-traditional contexts is a multiplier of bankability: it diversifies revenue streams, reduces exposure to the volatility of wholesale electricity markets and anchors the project to stable and predictable industrial demand.

This network of alliances is ultimately actively embedded in the European institutional architecture. The inclusion of Newcleo among the *Project Working Groups* of the European Industrial Alliance on SMRs is an operational channel for interacting with regulators, suppliers and potential financiers, accelerating the resolution of bottlenecks (European Commission, 2024). Its inclusion in a European framework reduces 'system' uncertainty and aligns the company's trajectory with the Union's strategic priorities on energy security and industrial competitiveness.

5.3 Bankability milestones, execution risks and Italy's strategic choice

Translating a technological and industrial strategy into a bankable project depends on three critical factors: access to capital, regulatory risk management and the credibility of the management team.

On the capital front, Newcleo has followed a trajectory typical of *tech* companies, combining private venture capital with the prospect of future public involvement. To date, it has raised over €535 million from private investors and *family offices,* and has stated its goal of raising up to €1 billion from institutional funds, with possible participation by the French state through Bpifrance (Nucnet, 2025). This multi-step financing strategy allows the project to be progressively de-risked, reaching technical and regulatory *milestones* that attract investors with different risk profiles.

Regulatory de-risking is perhaps the most critical aspect and the one in which Newcleo has made the most significant progress. The admission of its LFR-AS-200 design to the *Generic Design Assessment*

(GDA) process in the United Kingdom in June 2025 is a milestone (Modern Power Systems, 2025). This is the first time that an Advanced Modular Reactor (AMR) has been accepted into such a structured and rigorous regulatory review process. The value of this step is immense: by voluntarily submitting to one of the most demanding reviews in the world, Newcleo is moving towards a possible licence in the UK, and is also building an 'evaluation asset' (a body of safety documentation, analyses and responses to the regulator's concerns) that is largely transferable and reusable in other jurisdictions. This drastically reduces uncertainty for investors, who see a clear and traceable regulatory path, and accelerates future licensing processes in other European countries thanks to growing cooperation and mutual recognition practices among safety authorities (such as those promoted by ENSREG).

Management credibility is an intangible but crucial asset. Newcleo's founder, Stefano Buono, has a solid *track record* as an entrepreneur in technology- and regulation-intensive sectors. His previous company, Advanced Accelerator Applications, specialising in nuclear medicine, was successfully listed on the Nasdaq and subsequently acquired by Novartis for $3.9 billion (Reuters, 2017). This past experience in navigating complex regulatory procedures, raising significant capital and bringing cutting-edge innovation to market provides investors with fundamental confidence in the team's execution capabilities.

Analysis of the various SMR strategies in Europe reveals a heterogeneous competitive landscape, in which the choice of technology is inextricably linked to the industrial model and the chosen bankability lever. Newcleo clearly stands out from its LWR competitors by adopting a frontier innovation strategy, which involves a longer time horizon and higher technological risk, but promises greater added value in terms of fuel cycle sustainability and application versatility.

While LWR projects such as Rolls-Royce SMR, NUWARD and BWRX-300 aim to reduce risk by capitalising on mature technologies, existing supply chains and established regulatory pathways, Newcleo is betting on the ability of its fourth-generation LFR technology to solve problems that conventional SMRs only partially address. Closing the fuel cycle and supplying high-temperature heat are not marginal features, but the core of its value proposition, targeting a market that will require integrated solutions for the deep decarbonisation of industry and not just the electricity sector.

LWR competitors compete on speed of execution, reduction of perceived risk, and ability to leverage existing industrial ecosystems.

Newcleo, on the other hand, competes on another dimension: that of long-term strategic value. Its bankability does not depend on its ability to be the cheapest or fastest solution today, but on the credibility of its promise to offer a more complete and sustainable solution tomorrow, and on its ability to build an industrial and financial alliance capable of sustaining the long journey from development to commercialisation.

Despite the consistency of its strategy and the progress made, Newcleo's path to industrial deployment remains fraught with challenges. A critical assessment must recognise the residual risks and identify the execution levers that will be decisive for success.

The main risk is inherent in any *first-of-a-kind* nuclear project: execution risk, linked to possible delays in the construction time and costs of the first demonstrator. Although the partnership strategy with Maire aims to mitigate this risk for the conventional island, the construction of the LFR nuclear island will require the qualification of a supply chain for specific components (e.g. liquid lead pumps, heat exchangers) that have not yet benefited from serial production. A second type of risk concerns local acceptability. The localisation process in Chinon, France, has just begun with the launch of the public debate; its successful conclusion is a non-negotiable precondition for the project. Finally, the logistics of the MOX fuel cycle, although technically mature in France, present operational and safety complexities that will need to be managed with the utmost transparency and rigour.

The critical levers for success lie in the ability to continue to actively manage these risks. Financial leverage will be crucial: success will depend on the ability to maintain access to patient capital, willing to finance a long development horizon, and to convert the interest of public actors such as Bpifrance into concrete commitments. Contractual leverage will also be important: memoranda of understanding with industrial partners such as Danieli will need to be transformed into binding and bankable *offtake* agreements, providing the visibility on future revenues that is essential to attract project debt.

This scenario raises a crucial question for Italy, which faces an industrial policy dilemma. The national strategy, as outlined in Chapter 3, is moving on two tracks. On the one hand, through the industrial vehicle Nuclitalia, it is moving towards the selection of mature SMR technologies, with an initial focus on LWRs, to meet the need to deploy new programmable capacity in a relatively short time frame. On the other hand, Italy has a heritage of historical expertise in fast reactor technology and, through ENEA, hosts key research infrastructure for the development of LFRs. Newcleo, with its Italian roots but its operational and strategic centre of gravity in France, exemplifies this tension.

Italy finds itself having to choose between two strategic paths that are not necessarily alternative, but which require different priorities and resource allocations. It could purchase mature SMR-LWRs, such as those proposed by Newcleo's competitors, to accelerate decarbonisation, positioning the national supply chain (as advocated by the Confindustria-ENEA report) as a supplier of components and services in a programme led by foreign technologies. Or it could position itself as *a technology developer* and actively support an AMR project such as Newcleo's, accepting a higher risk and a longer time horizon, in the hope of cultivating a 'national champion' capable of competing as a leader in the fourth-generation market.

This choice is not binary but requires a clear strategic vision. The 'Newcleo case' forces Italian political and industrial decision-makers to confront a fundamental question: 'What role does Italy want to play in the European nuclear renaissance? That of a customer or that of an innovator?'. The answer to this question will define the trajectory of the country's industrial policy for decades to come.

Chapter 6: Nuclear in Italy: a strategy for action

6.1 Newcleo as a test case for project finance readiness

The previous chapters of this thesis have sought to outline a framework for understanding the complex resurgence of the nuclear debate in Italy and Europe, culminating in the analysis of the Newcleo case in Chapter 5. This concluding chapter sets itself a further objective: to translate the analysis from a descriptive dimension to a proposal. Drawing on the valuable primary information gathered during the interview and presentation with Newcleo's institutional representatives, this chapter aims to use their case as a test bed for the theoretical concepts previously explored and, on this basis, formulate a concrete political and industrial agenda for Italy (Newcleo, 2025).

Newcleo's approach, with its emphasis on Generation IV technology, the closed fuel cycle and a sophisticated partnership model for risk mitigation, offers a practical application of the concept of bankability introduced in Chapter 4. Their strategy seeks to resolve historical critical issues such as safety, waste management and economic sustainability that have led to the abandonment of nuclear power in Italy. This chapter will use this perspective to address the 'nuclear investability trilemma' in Italy, a Gordian knot consisting of three interrelated challenges that must be resolved simultaneously: risk management (political, regulatory, construction and market), ensuring adequate remuneration that recognises the systemic value of nuclear energy, and building a solid social and institutional consensus (World Nuclear Association, 2024). The ultimate goal is to outline a strategic roadmap that not only allows for the reintroduction of advanced nuclear power into the national energy mix, but also positions Italy as a leading player, rather than a mere spectator, in the European nuclear renaissance.

Before formulating policy recommendations, it is essential to critically analyse Newcleo's strategy, also assessing its alignment with the Italian and European political and economic context. The company's strategy is based on two pillars: a distinctive technological proposal and an industrial model based on risk reduction.

The core of Newcleo's proposal lies in a precise and doubly strategic technological choice: a fourth-generation Lead-cooled Fast Reactor (LFR), combined with a closed fuel cycle based on the use of Mixed Oxide Uranium and Plutonium (MOX) (Newcleo, 2024). This combination, in addition to representing a valid engineering preference, is also a calculated response to the two main objections that have historically fuelled public opposition to nuclear power in Italy and elsewhere: plant safety and radioactive waste management.

From a safety perspective, LFR technology eliminates some of the most feared accident scenarios at their root. Operating at atmospheric pressure, unlike typical pressurised water reactors, it virtually eliminates the risk of accidents due to high-energy coolant loss. The intrinsic properties of liquid lead (high boiling point, high thermal inertia and chemical inertia) ensure passive cooling of the reactor in the event of anomalies, allowing ample time for corrective action without the need for complex active safety systems or human intervention (World Nuclear Association, 2023). This 'intrinsic safety' feature is a powerful narrative tool, as it shifts the paradigm from 'managed' safety (entrusted to redundant systems) to safety 'built into' the physical laws of the system.

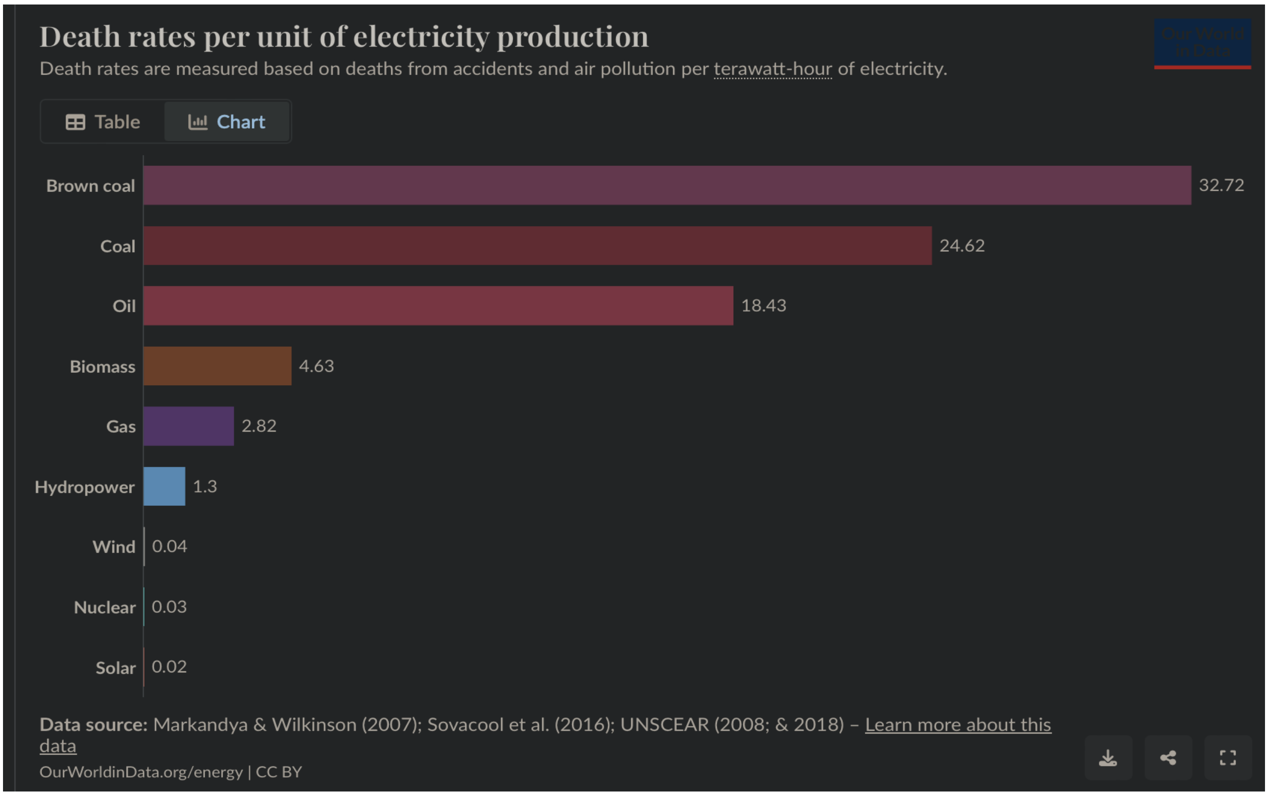


Figure 6 - Mortality rates per terawatt hour (accidents and pollution) for different electricity generation technologies. Fossil fuels have significantly higher values; nuclear and wind/solar are at much lower levels. Source: Our World in Data, based on UNECE/IPCC.

The second element, the closed fuel cycle, addresses the long-standing problem of nuclear power: the long-term management of waste. By using MOX fuel, produced from the spent fuel of traditional reactors, Newcleo transforms a liability (waste) into an asset (an energy resource). This approach not only drastically reduces the volume and long-term radiotoxicity of final waste, but also changes the very perception of the problem, shifting from a disposal to a recycling mindset, while reducing the need for natural uranium (OECD-NEA, 2019).

The real breakthrough of this technological choice lies not only in its technical merits, but also in its strategic and political alignment with France. France is the only country in the world to have a mature, large-scale industrial infrastructure for reprocessing spent fuel and manufacturing MOX, concentrated in the Orano plants in La Hague and Melox (Orano, 2024). French energy policy has been based on a closed-cycle strategy for decades, and the management of its plutonium and spent fuel stocks is a national priority. This alignment with the interests of an important European Union state with a strong nuclear tradition is a powerful factor in reducing both political and industrial risk. It also ensures access to an existing and qualified supply chain and creates a strong incentive at the state level for the company's success, a factor of stability that is far more solid than abstract technological superiority.

Aware that a *first-of-a-kind* (FOAK) project is burdened by a risk profile that private capital can hardly absorb in its entirety, Newcleo has built an industrial model based on a network of partnerships that can be interpreted as aimed at risk unbundling, as already indicated in Chapter 4. This strategy is structured along three complementary lines.

The first line of risk reduction is on the technological side. As a partner of two of Europe's leading nuclear research centres, ENEA in Italy and CEA in France, Newcleo not only has access to world-class expertise and infrastructure, but also legitimises its development path (World Nuclear News, 2024). The collaboration with ENEA for the construction of the non-nuclear PRECURSOR prototype at the Brasimone Centre is a crucial step in validating the thermohydraulics and mechanics of the system before tackling the complex and costly nuclear licensing phase (ENEA, 2023). Similarly, the partnership with CEA on critical aspects such as fuel qualification effectively places Newcleo's development within the French technological strategy.

The partnership with Nextchem (Maire Group) for the design and construction of the "conventional" part of the plant, i.e. the part that converts heat into electricity but does not contain the nuclear reactor, is a strategic move (World Nuclear News, 2023). This is because it separates the risks: those related to nuclear technology, which are new, complex and not entirely predictable, from those related to the traditional construction of a plant, which are well known and manageable. This division makes the project safer and more attractive to investors and companies operating in the traditional industrial sector. The agreement with the Tosto Group, which specialises in heavy components, is also very important. Instead of being a simple paid supplier, Tosto becomes a partner in the project through a *'work for equity'* mechanism. This means that Tosto provides its services and, in return, receives a share of the company. In this way, the supplier itself becomes a real investor, becoming a stakeholder and aligning everyone's interests towards the success of the project and ensuring stronger collaboration for the production of critical components.

We can also note the mitigation of market risk. Newcleo's strategy perfectly embodies the shift from Levelised Cost of Energy (LCOE) to 'system value'. By positioning itself as a provider of integrated energy solutions, the company diversifies its revenue streams and ensures stable demand. The LFR reactor's ability to provide high-temperature process heat makes it ideal for the decarbonisation of *hard-to-abate* industries. Memoranda of understanding with large industrial consumers such as Danieli are the first step in transforming this potential into long-term *offtake* contracts. The latter, if signed with large customers (e.g. Danieli), guarantee that part of future production is already sold at a fixed price. This makes revenues certain and stable, protecting the project from market volatility and facilitating the obtaining of the necessary financing (Newcleo, 2025).

Explorations in unconventional sectors, such as supplying offshore platforms with Saipem or naval propulsion with Fincantieri, further expand this horizon, demonstrating a vision that goes beyond simple competition on the price per MWh and focuses on creating value through the supply of *'clean firm* power' in multiple forms (Wärtsilä, 2022). This approach, which we could define as *'value* stacking', is a central element of their bankability strategy. It is a widely recognised business model in the energy sector, which is not limited to generating value from a single source (the sale of electricity), but combines multiple services and revenue streams from the same asset. In this specific case, explorations in sectors such as naval propulsion (Fincantieri) or offshore platforms (Saipem) demonstrate that it is not only the energy produced that generates value, but also the provision of specialised *'clean and reliable energy'* solutions. This diversifies potential markets and revenue streams, making the project more robust and attractive to investors (Lazard, 2024).

6.2 Financing framework for project viability

The Newcleo case study shows that bankability is not a spontaneous market condition, but the result of deliberate institutional, financial and political engineering. For Italy, whose nuclear path has been abruptly interrupted, the challenge is even more complex. It is necessary to build from scratch an architecture that can resolve the 'trilemma' of risk, remuneration and consensus. Below is a three-pillar policy agenda that integrates and expands on the recommendations outlined above.

The main obstacle to financing nuclear projects in market economies is their risk profile, which assumes high capital intensity, long construction periods and high sensitivity to the cost of capital (WACC). An effective financial strategy must divide these risks and allocate them to the actors best positioned to manage them.

First and foremost, the market risk associated with the volatility of wholesale electricity prices must be significantly reduced or neutralised. As highlighted in the Draghi Report, long-term contracts are essential for the stability of investments in *capital-intensive* energy assets. It is therefore recommended that a competitive auction mechanism be established for the allocation of *two-way Contracts for Difference (CfDs)* for new *clean firm* capacity. This instrument, which guarantees the producer a fixed price (*strike price)* for the energy produced, would eliminate uncertainty about future revenues, stabilise cash flows and drastically reduce the risk perceived by equity investors, lowering the cost of equity. One example is Hinkley Point C in the UK, whose financing was approved by the European Commission in 2014, prior to the Brexit referendum. This project demonstrated the possibility of obtaining state support, a path that will be further facilitated for future nuclear projects within the EU by the new European framework for state aid (CISAF), which explicitly recognises advanced nuclear as a strategic technology (European Commission, 2014).

The second component must mitigate construction risk, the main deterrent to private debt financing. The British *Regulated Asset Base* (RAB) model socialises this risk by transferring it directly to consumer tariffs, a politically problematic option for Italy given its high energy costs (UK Government, 2022). A more suitable approach is inspired by *the Loan Programmes Office* (LPO) of the US Department of Energy, which uses public guarantees to absorb specific risk shares that the market is unable to price (US Department of Energy, 2024). We therefore propose the creation of a *Public Guarantee Fund,* managed by an entity involving the Ministry of Economy and Finance (MEF) and Cassa Depositi e Prestiti (CDP). This entity would create a fund that does not provide direct financing but would provide a *state guarantee* on a significant portion (e.g. 80-90%) of the debt for the first 2-3 SMR/AMR projects. This model is a proven strategy for unlocking private financing for large-scale projects (World Nuclear Association, 2025), acting as a powerful catalyst that makes access to debt capital from commercial banks and institutional investors much more favourable.

The choice of this hybrid model (CfD and Public Guarantee) responds to a specific political economy logic. Unlike the British RAB model, which imposes a direct and immediate cost on consumers, the public guarantee represents a potential debt on the state budget. This allows public support to be framed not as a burden on the bill, but as a long-term strategic investment in the country's energy security and industrial competitiveness, a vision that aligns perfectly with the strategic priorities outlined in the Draghi Report (Draghi, 2024).

The third component is the strategic role of development finance. In this context, Cassa Depositi e Prestiti (CDP) should act as *an 'anchor investor*'. This term refers to a primary and fundamental investor who commits to providing a significant amount of capital in the early stages of a financial transaction. Its presence is crucial because, in addition to providing a solid financial base, it also acts as a powerful signal of confidence for the market, reassuring other potential investors (Chen, 2023). CDP's role as *an anchor investor* would fill a gap in financing while sending a strong signal to the market, facilitating the attraction of additional private capital and the structuring of the entire financial transaction.

The table below summarises the proposed risk mitigation architecture, systematically mapping the main risk categories with mitigation tools, responsible actors and international precedents. To further maximise the benefits of advanced nuclear power, a policy framework that recognises and remunerates its full economic value is essential. A two-stage intervention is recommended. On market design reform and system-value remuneration see Chapter 4, section4.4; here I assume that framework and focus on the contract architecture (two-way CfD + public guarantee) and on the roles of CDP/EIB

6.3 Social licence through transparent governance

To overcome the socio-political barrier inherited from the referendums, a new approach to governance is needed, based on transparency and shared benefits. Italian public opinion data show a deep generational divide, with younger cohorts (18-35 years old) significantly more favourable (78% open to the idea) than older ones (over 55 years old), where 58% remain opposed (SWG, 2024). These polls also indicate a strong correlation between support for nuclear power and the perception of a direct economic benefit, such as lower energy bills.

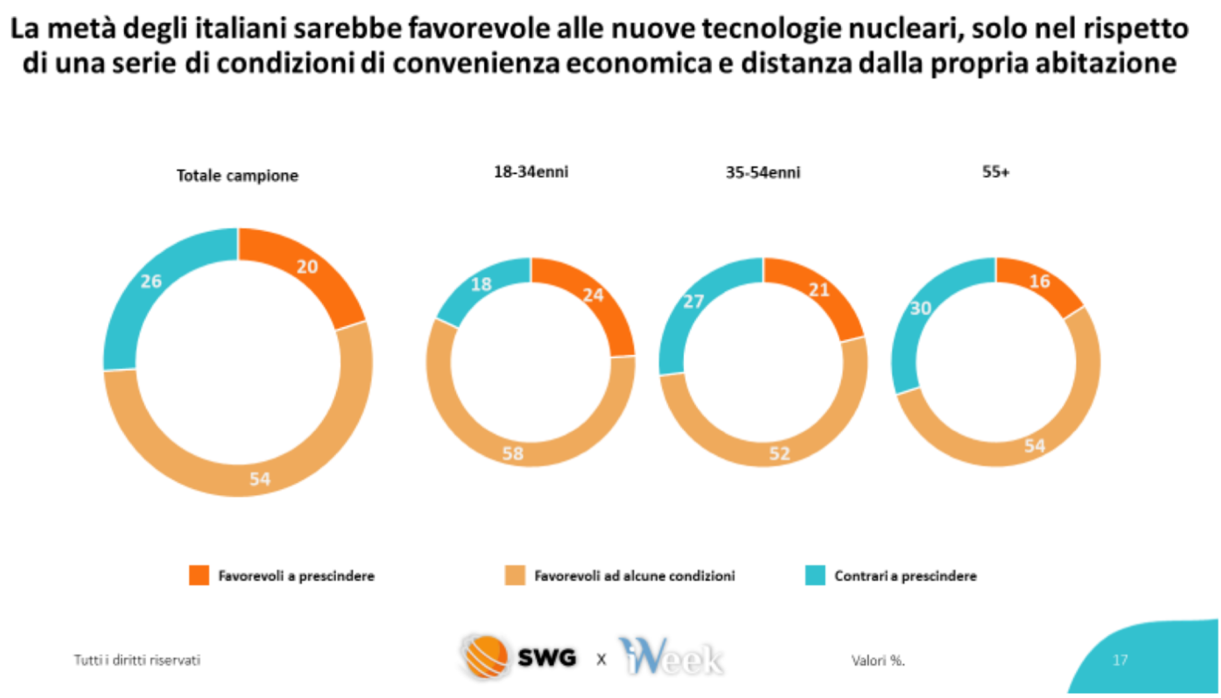


Figure 7— Support/opposition to the construction of new nuclear power plants/new nuclear technologies in Italy by age group. The proportion of those in favour is significantly higher among 18–34 year olds than among the over-55s. Source: SWG, i-Week – national survey (October 2023)

This generational divide is not a critical issue, but a strategic opportunity. It suggests that historical opposition, linked to memories of past accidents, is fading with demographic change. A long-term nuclear strategy will mature in a political context where today's younger, more favourable voters will form the core of the electorate. Communication and policy must therefore be geared towards this future, focusing on issues such as climate, technological innovation (Gen-IV) and economic competitiveness, rather than attempting to reopen past debates.

To capitalise on this trend, three governance actions are proposed. The first is to formalise Participatory Governance by institutionalising the *National Platform for Sustainable Nuclear Energy* (PNNS*)* as a permanent forum for transparent dialogue between institutions, industry, academia and civil society (Ministry of the Environment and Energy Security, 2023). The second would be to make the Pathway to a National Repository credible, accelerating the siting process with maximum transparency and public participation, inspired by the public debate models used in France for the *Cigéo* project *(*Sogin S.p.A.; Andra, 2025). Finally, a benefit-sharing model should be established with a national fund, financed by a small royalty on the production of the new plants, to provide direct economic benefits (e.g. reduction of local taxes, investment in services and infrastructure) to the communities that will host the plants (OECD Nuclear Energy Agency, 2024). This would effectively link the presence of a nuclear plant to the well-being of the local area, directly responding to the economic sensitivity that emerged from the surveys.

6.4 Dual track Roadmap for Italian Leadership

The analysis conducted so far leads to a fundamental strategic choice for Italy: to position itself as a simple 'adopter' of mature nuclear technologies developed elsewhere, or to aspire to a role as a 'developer' and leader in fourth-generation innovation. The comparison between light water SMRs (LWRs), which are an evolution of established technologies, and Newcleo's AMR, which is at the cutting edge of technology, embodies this dilemma.

There is no single answer. A pragmatic approach must recognise both the urgency of decarbonising and ensuring energy security in the short to medium term, and the long-term strategic opportunity to rebuild industrial leadership in a sector with very high added value. A *two-track strategy* is therefore recommended (World Nuclear Association, 2024).

Track 1: adoption and implementation, horizon 2035

To meet the ambitious decarbonisation targets set for 2030-2035 (MASE, 2023), Italy should focus on the adoption and implementation of a mature and technologically proven SMR design, with an international licensing process already well advanced. This pragmatic path would allow results to be achieved relatively quickly, demonstrate the feasibility of the projects and, above all, rebuild the skills lost over the years and the capacity of the national industrial supply chain on a solid technological basis, exploiting the existing heritage of over 70 specialised companies.

Track 2: innovation and leadership: horizon 2040 and beyond

At the same time, Italy must invest strategically in research and development to become a leader in the next generation of nuclear technology. This means actively supporting 'national champions' such as Newcleo and promoting unique assets such as the ENEA research centre in Brasimone, a world leader in lead-cooled fast reactor technology. The goal of this track 2 is not to be a passive *technology taker,* but to increasingly become *a technology maker,* positioning Italian industry to capture a significant share of the future global market for fourth-generation reactors (ENEA, 2024). If the reconstruction of industrial capacity achieved in track 1 is successful, it will create the political, economic and technical foundations necessary to support the longer-term, higher-yield investment of track 2. In this way, Italy can solve its immediate energy needs and, at the same time, cultivate industrial leadership for the future.

Chapter Conclusions: Towards Italian Leadership in the European Nuclear Renaissance

The reintroduction of nuclear energy in Italy transcends the purely technical or energy dimension to become a choice of industrial policy and strategic positioning of primary importance. The analysis conducted in this chapter, enriched by the direct perspectives of an innovative player such as Newcleo, shows that a successful path is neither simple nor obvious, but it is certainly possible.

The bankability of advanced nuclear energy will not emerge spontaneously from the market; it must be pursued through deliberate, consistent and multidimensional political action. The agenda proposed here (based on a hybrid financial architecture for risk mitigation, a market design that rewards systemic value, a new social contract based on transparency and shared benefits, and a dual-track industrial strategy) offers a concrete roadmap for achieving this goal.

By adopting a proactive approach, Italy has the opportunity to transform its historical energy vulnerability and troubled nuclear past into a strategic advantage. It can not only meet its security and decarbonisation imperatives, but also establish itself as an innovation hub and a credible leader in the renaissance of advanced nuclear power in Europe, helping to shape the continent's energy and industrial future (Draghi, 2024).

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