# The potential of the EU to lead the SMR race

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# Table of content

# Executive summary

The European Union (EU) is entering a critical phase in the definition of its long-term energy policy. Small Modular Reactors (SMRs) have emerged as a potential transformative technology, promising cheap, low-carbon, reliable, and non-intermittent electricity generation. The opportunity for the EU to lead or at least compete in the SMR industry will be open for a handful of years. However, SMR deployment in the EU faces significant bottlenecks, including regulatory, financial, and workforce-related challenges, which may be exacerbated by the Union's institutional and market characteristics and may prevent the EU to successfully joining this technology progress.

This paper examines these constraints and proposes policy and market-oriented solutions from a liberal perspective, focusing on regulatory reform, financing mechanisms, technological development, and workforce capacity. It argues that, if the current framework remains unchanged, SMRs are unlikely to achieve cost competitiveness and may depend heavily on public support, similarly to, or more than, conventional large-scale nuclear projects.

A substantial redesign or adaptation of the EU's nuclear regulatory and legislative framework would be required for SMRs to become not only a reality, but a useful reality for the EU.

# Foreword by European Parliament Vice-President Sophie Wilmès

In recent years, the European Union has been reminded of a reality that can no longer be ignored: affordable energy, energy security, competitiveness and climate ambition must go hand in hand. The geo-energetic shocks following Russia's invasion of Ukraine and the tensions in the Middle East, growing concerns about industrial competitiveness, and the EU's ambitious decarbonisation path have all demonstrated the need for a pragmatic and technology-neutral approach to energy policy, far from dogmatism and preconceived ideas.

For several years, I have advocated for such an approach. As Vice-President of the European Parliament and within the Renew Europe family, I have consistently argued that achieving climate neutrality requires mobilising all low-carbon technologies capable of contributing to our common objectives. This conviction was reflected in Renew Europe's position paper on Small and Advanced Modular Reactors published in March 2026, which recognised the potential of SMRs to strengthen Europe's energy sovereignty, strategic autonomy, industrial competitiveness and decarbonisation efforts and outlined 8 concrete actions to put Europe at the spearhead of SMR development.

SMRs will complement the continued deployment of renewable energy and conventional nuclear energy. They are, indeed, a necessary complementary pillar for Europe to achieve a carbon-neutral energy mix and to reinforce the resilience of our energy system. Their potential to provide reliable, locally produced, low-carbon electricity and heat, supporting industries, remote regions, cities, ports, data centres and hydrogen production, deserves the highest level of political attention.

Europe cannot afford complacency. While other global actors are moving rapidly to develop and commercialise SMR technologies, Europe risks falling behind despite its scientific excellence, industrial capabilities and long-standing expertise in nuclear energy. If we want to remain a global leader rather than become dependent on technologies developed elsewhere, we must actively create the right conditions for innovation and investment.

This requires addressing a number of persistent challenges, which are highlighted in this paper. Regulatory fragmentation, lengthy licensing procedures, financing barriers and workforce shortages continue to hamper the emergence of a truly European SMR ecosystem. Overcoming these obstacles will require political courage, regulatory cooperation and a clear commitment to technological neutrality.

This paper makes a timely contribution to that debate. It offers a bold reflection on the opportunities and challenges associated with SMR deployment in Europe and proposes a series of avenues to unlock their potential. While not every recommendation will necessarily command universal agreement, including on my part, and some are likely to spark debate, the central question it raises is an important one: how can Europe ensure that innovative low-carbon technologies have a fair opportunity to contribute to our shared energy future?

As policymakers, our responsibility is not to pick winners, but to create the framework in which innovation, competition and technological progress can flourish. Europe has the talent, the expertise and the industrial foundations to succeed in the SMR race. Europe now needs the political determination to seize this opportunity before the window closes.

Sophie Wilmès

*Vice-President of the European Parliament,*
*Member of the European Parliament (Renew Europe Group)*
*and Substitute Member of the ITRE Committee*

# Chapter 1. The Problem

Europe faces a triple crisis in its energy sector: a crisis of *energy security*, a *crisis of energy resilience*, and a crisis of *energy externalities*, i.e. a climate crisis. This problem was highlighted by President Von der Layen in her *"energy trilemma"*[1] speech. Addressing it requires a clear warning 2026 is not 2016. The assumption that the same political initiatives, legislative actions, and planning made a decade ago will function today is proven to be wishful thinking and does require a sharp change of direction[2].

> *The greatest danger in times of turbulence is not the turbulence—it is to act with yesterday's logic.*
>
> Peter Drucker

The Russian invasion of **Ukraine** shattered the illusion of secure, affordable imported hydrocarbons, exposing a critical strategic vulnerability. The **record-breaking temperatures** of 2024 underscored the accelerating and existential threat of climate change, demanding a rapid, scalable decarbonisation of our power grid. And finally, the **historic Iberian blackout** of 28 April 2025, was an unforgiven warning: Either Europe solves this trilemma in the next few years, or it will suffer the consequences for decades.

In terms of **energy security**, the EU has been fundamentally undermined by a heavy **reliance on imported fossil fuels**, particularly natural gas from politically volatile regions. Europe's dependence on imported fossil fuels, which stood at approximately 58% of gross energy consumption in 2022, has elevated energy security to a central political and economic concern. This dependency exposes the European economy to the interests and agendas of foreign powers, creating a strategic vulnerability where energy can be used as a geopolitical lever. The 2022 Russian invasion of Ukraine served as the ultimate catalyst, demonstrating that the perception of secure and affordable hydrocarbon imports was a dangerous illusion that threatened the very sovereignty of Euro-

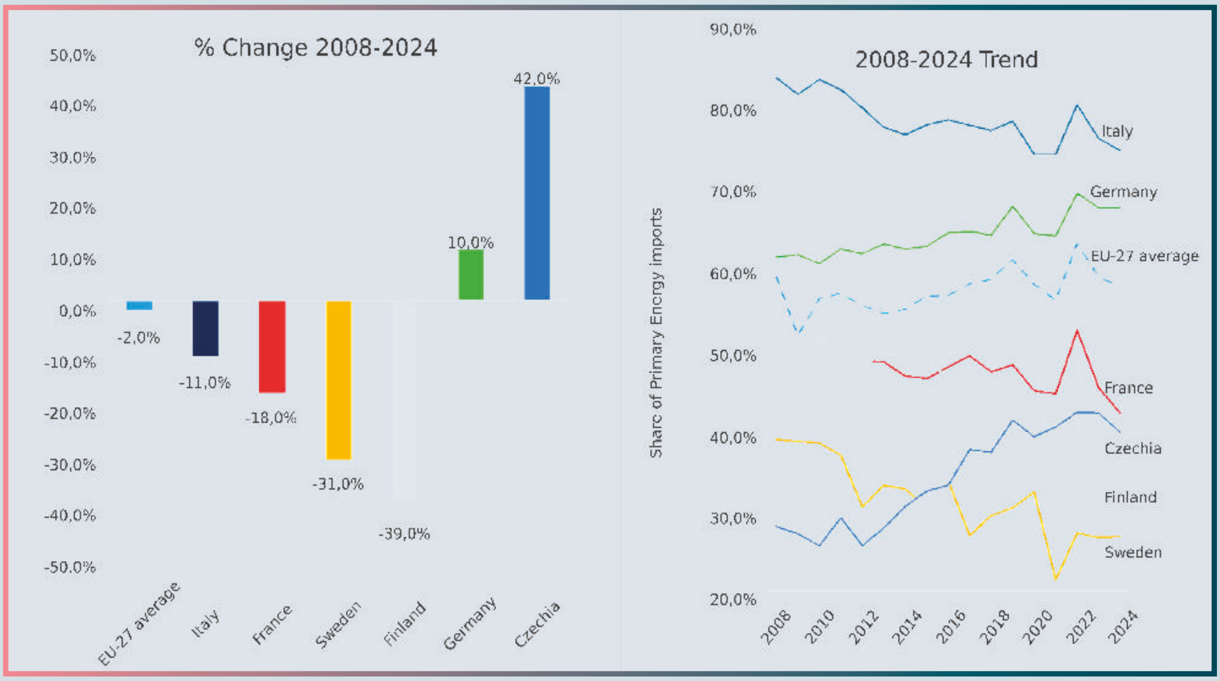
1 Speech by President von der Leyen at the Nuclear Energy Summit, "Check against delivery", https://ec.europa.eu/commission/presscorner/detail/en/speech_24_1624, 2024

2 *On the Urgent Need of a Nuclear Energy Strategy for Europe*. 2024 High Scientific Council of the European Nuclear Society. https://www.euronuclear.org/scientific-resources/position-papers/

pean states. At the same time, tensions involving Iran and the Strait of Hormuz, within the broader context of the US–Iran conflict, confirm the vulnerability, namely exposure to geopolitical disruptions affecting critical energy transit routes and global markets.

Figure 1 tracks energy import dependency across the EU-27 alongside six major EU economies from 2008, at the onset of the Euro area crisis, to 2024. Over this period, the EU-27 aggregate has remained persistently elevated, fluctuating between 54% and 63% without exhibiting a sustained downward trend, and is therefore better understood as a structural condition rather than a cyclical fluctuation. The most striking feature is the sharp increase to 62.5% in 2022, the highest level recorded in the series, which directly reflects the supply shock triggered by Russia's invasion of Ukraine and the abrupt disruption of gas and other fossil fuel flows that had long underpinned European energy balances. The subsequent partial decline to 58.3% in 2023 and 57.2% in 2024 provides only limited reassurance, as the EU remains broadly as import-dependent today as it was in 2008, having made little substantive progress towards greater energy autonomy over the past sixteen years.

**Figure 1.** Change in Energy Import from 2008 (left) and Share of primary energy import (right)



The crisis of **energy resilience** is centred on the ability of the power grid to maintain stability and recover from unexpected shocks. As the share of intermittent renewables grows, the grid loses **"synchronous inertia"** (the kinetic energy stored in the rotating masses of traditional turbines) which is vital for resisting frequency changes and preventing cascading failures. Without this built-in resilience, minor disturbances can rapidly escalate, as evidenced by events like the historic Iberian blackout where insufficiently responsive control resources led to total grid collapse.

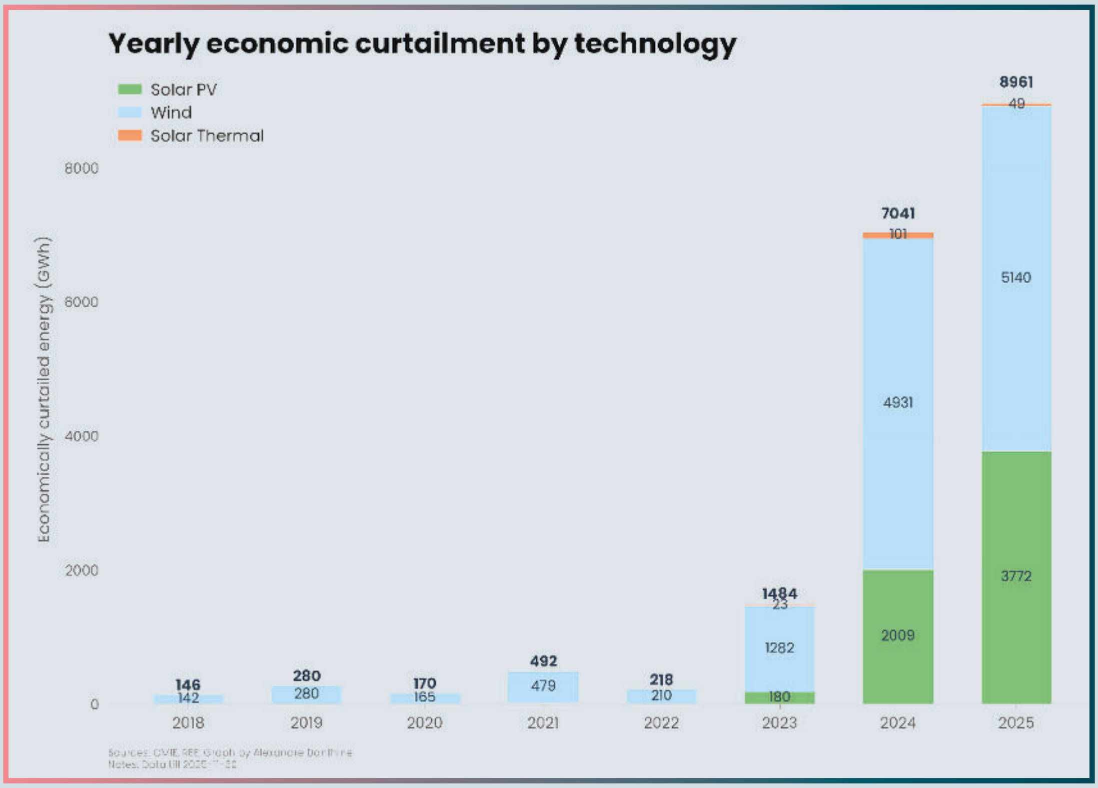
The **climate crisis** represents an existential externality, a **"progressive disease"** driven by the accumulation of greenhouse gases from fossil fuel combustion. Addressing this crisis requires more than just incremental changes; it demands a massive, multi-sectoral shift towards electrification in heating, transport, and industrial processes to replace the fossil fuel industry on a global scale. The unprecedented temperatures of recent years underscore the urgency of this transition, as the uncertainties of runaway warming threaten **trillions of dollars in costs** and civilisation-scale disruption.

One of the best allies to help address those issues is **renewable energy** (in particular, wind and solar). Europe has been pushing for renewable energy since decades ago, and they play a significant role in addressing the energy trilemma.

Renewable energy serves as a critical tool for energy security by enabling the production of **"homegrown" power** that is independent of international commodity markets by shifting away from imported hydrocarbons. Also, renewables contribute to energy resilience through the **decentralisation of the power system**, moving away from a few massive, vulnerable production hubs towards a more distributed architecture. This shift can create a grid where local demand is increasingly met by local generation, which can help compartmentalise failures and reduce the risk that a single point of failure in a centralised system could trigger a wide-scale blackout. Finally, the primary environmental benefit of renewables is their near-zero $CO_2$ emission profile during operation, making them indispensable for achieving the European Union's ambitious **Net-Zero targets**. These resilience benefits only materialise when paired with sufficient synchronous inertia and dispatchable generation; without adequate baseload support, high renewable penetration can paradoxically increase grid vulnerability.

Renewables by themselves are not able to completely solve the trilemma. Despite their benefits, renewables face some technological hurdles, primarily their inherent **intermittency, variability and low energy density**. In Europe, the average annual output for wind is often as low as 22% of nameplate capacity, with long lulls or *Dunkelflaute* where output drops below 10%, necessitating a parallel dispatchable system. Current battery technology is **prohibitively expensive** for bridging these multi-day lulls, with costs for a reliable system rising into the hundreds of billions and potentially reaching into the trillions of euros. Furthermore, high solar penetration during peak hours can drive energy prices to zero, leading to "death by capacity factor" where excess electricity must be curtailed or **"thrown away"** to maintain grid stability3, see Figure 2. This phenomenon spiralled and was notably observed in Spain in April 2025, where high shares of renewables combined with low grid inertia contributed to the conditions for the blackout4.

**Figure 2.** The trajectory of economic curtailment in Spain over the past eight years




3 https://alexandredanthine.substack.com/p/five-years-of-spanish-curtailment
4 Euronews. https://es.euronews.com/2026/03/24/audios-apagon-28-a-fallos-sistema-electrico-espanol-dias-antes-colapso

The EU needs to be capable of **exploiting renewable energy to its full potential**. Nevertheless, in order to extract the enormous benefits that renewables can bring (of already mentioned independence, carbon-free and affordability) the EU needs another ally. This ally has historically proven itself to be nuclear power; Nuclear energy is the best partner for renewables to reach their full potential.

By observing the country-level divergence in energy import (Figure 1), the data becomes analytically most revealing of this **fruitful nuclear-renewables cooperation**. France, Finland, and Sweden, all significant producers of nuclear and renewable energy, have each recorded meaningful reductions in import dependency over the same period, with overall changes of -18%, -39%, and -31%, respectively, between 2008 and 2024. By contrast, Germany and Italy have either moved in the opposite direction or remained broadly stable. Germany's dependency increased from 60.8% to 66.8%, a trajectory that accelerated following the post-Fukushima decision to phase out nuclear generation. Italy, by contrast, which has had no nuclear capacity since 1990, has remained consistently above 73%.

Nuclear power acts as the essential partner to renewables by providing the **"clean baseload" and "dispatchable" power** they lack. Unlike wind and solar, Nuclear Power Plants (NPPs) provide the vital **synchronous inertia** required to maintain grid frequency and stability. By offering high energy density and constant availability, nuclear energy can carry the load during renewable lulls, reducing the need for destructive amounts of resource-intensive battery storage and ensuring that the overall energy system remains reliable, affordable, and CO2-free.

Nevertheless, EU has been struggling to develop nuclear power in the last decades. Large nuclear projects of the latest reactor technology like Hinckley Point C in the UK, Flamanville in France or Olkiluoto in Finland have pointed out important flaws in the construction process. Those projects have been extensively delayed, with construction costs greatly expanded and making new nuclear power large projects a not-so-affordable option. Finland's **Olkiluoto 3**, initially budgeted at €1,700/kW for a 5–year build, multiplied by four its initial costs and took 16 years to complete in 2023. Similarly, France's **Flamanville 3** saw its costs soar from €1,700/kW to €12,900/kW over 17 years. The UK's **Hinkley Point C** project is currently estimated to cost at least **€15,500/kW** with a construction period exceeding **12 years by 2026**, expected to be completed in 2030 and making it the most expensive nuclear project globally. These "megaprojects", summarised in Table 1, have demonstrated the flaws of the current model of building new large nuclear power plants.

**Table 1.** Costs and construction times of nuclear projects in western countries.

| | *CAPEX in €/kW* | *Build Years* |
|---|---|---|
| *Olkioluoto (Finland)* | 6900 | 16 |
| *Flamanville 3 (France)* | 12900 | 17 |
| *Hinkley Point C (United Kingdom)* | 15500 | More than 12 |
| *Vogtle 3/4 (USA)* | 13400 | 14 |
| *Oconee (USA, built in 1970s)* | 1000 | 5 |

This may come as a surprise, since nuclear power has been historically a cheap source of energy, able to compete with coal in the 70s, when coal was as cheap as it has ever been.[5] The NPP of Oconee was built in the 1970s for approximately 1000 €/kW in 2026 money, see Table 1. Contrary to intuition, nuclear construction has not become faster and more affordable over time following advancements in efficiency learned from experience. The usual progress path, like the one followed by mobile phones, water boilers or cars, has not been found. Instead, nuclear projects have evolved in the opposite direction, becoming slower to build and more costly over time. If nuclear power is to help in solving the energy trilemma, it may not be able to do it on its current form. Already built reactors will greatly support, especially with the so-called "Long-Term Operation" (LTO), but even if they extend their operation to 60 years like some US nuclear power plants (NPPs), at some point they will need to be replaced in the next decades. The question is then: what will they be replaced with?

In this turbulence, a conventional policy response to the energy trilemma i.e. doubling down on centralised planning, complex subsidies, and rigid mandates, threatens to further distort markets, stifle innovation, and erode economic liberties. Europe requires a different path and now there is a window of opportunity to harness technological innovation to deliver clean, secure ener-

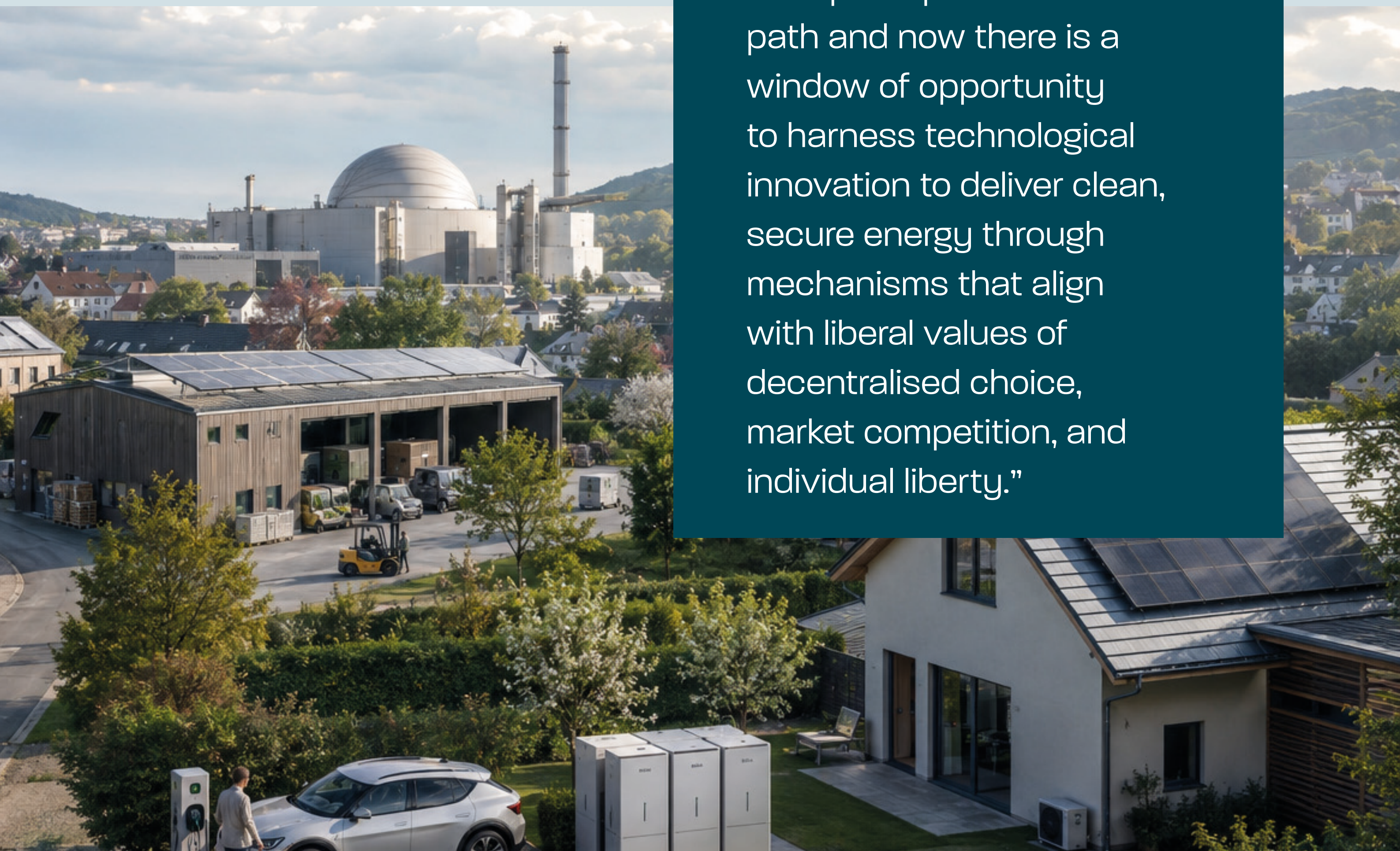
5 Crowley et al. 1981. Energy Economic Data Base (EEDB) Program. Phase III. Final report and third update.

gy through mechanisms that align with liberal values of decentralised choice, market competition, and individual liberty.

This path is embodied by **Small Modular Nuclear Reactors (SMRs)**. Unlike the monolithic, state-led nuclear projects of the past, SMRs could represent a market paradigm shift. SMRs, differ from the previous designs in that they are 5-10 times smaller in power, their modularity, factory fabrication, and inherent safety features open the door to a more competitive, diverse, and dynamic energy landscape. They offer a genuine market solution for firm, zero-carbon power that can complement renewables, re-industrialise Europe, and reduce geopolitical dependencies. They could be the perfect companion of renewable energy in the EU, securing the future of EU's energy demand.

But there is an even higher prize SMRs could open the door to. This reward will be something that EU's citizens will be benefiting from for a long period of time. This is, a nuclear energy market that will approximate to a free-market based on competitiveness and adequacy of the design; a market driven by consumers.

"Europe requires a different path and now there is a window of opportunity to harness technological innovation to deliver clean, secure energy through mechanisms that align with liberal values of decentralised choice, market competition, and individual liberty."



The theoretical appeal of SMRs lies in their ability to break the almost "null competition" that large-scale nuclear designs have exhibited in the past. By shifting from on-site construction to factory fabrication and therefore decreasing entry barriers, SMRs aim to leverage classic market efficiencies. Nonetheless, this free-market thesis must be assessed accordingly.; a high-level comparison would look like the following Table.

**Table 2.** A high-level comparison of Large-scale nuclear against the theoretical yet-to-prove Small Modular Reactors

| | Large-Scale Nuclear | SMR Free-Market Theory |
|---|---|---|
| Capital Cost | Very high; requires State backing | Significantly reduced; manageable for private actors |
| Construction Time | Decade-long timelines | Target of approximately 2-4 years |
| Regulatory Complexity | Bespoke and site-specific | Simpler, safer designs; easy to license |
| Market Competition | Limited to state-backed entities | Multiple vendors competing on cost and quality |

However, this liberal energy future is absolutely not guaranteed, nor easy to achieve in the current state of the EU. The opportunity is real, but the window is closing; estimated at no more than seven years[6]. The race for SMR technological and industrial leadership is global, with North America and Asia advancing rapidly. Europe risks being left behind, not by a lack of scientific excellence, but by self-imposed regulatory and political bottlenecks.

We will examine in detail the main bottlenecks for full deployment the SMRs will suffer in Chapter 2. The next chapters will focus on remedies, actions and options to be able to reach a cohesive EU in which a market for SMRs to flourish.

6 7 years estimated due to the current momentum and building permits, estimated as the time at which US and China would have established themselves as dominant players after first built has already take place.

# Chapter 2. Are Small Modular Reactors small enough to pass through the bottleneck?

For SMRs to flourish, they will have to be freed of several bottlenecks. Right now, more than 80 designs are on the workbench, and many of them will not see the "finishing line" of building and operating a successful fleet of reactors. This is natural path of any competitive market; many designs die before commercialisation because competitors outscore them. However, the dropout of those designs may happen at different bottlenecks, and some of these bottlenecks do not have much to do with consumer satisfaction and are more related to bureaucracy hurdles or worst, informal political influences.

While the free market theory is seductive, the "real life" implementation of SMRs faces a defensive perimeter of institutional barriers that favour stagnation over competition. In this chapter, we will scrutinise the different bottlenecks that the SMRs are facing.

## 2.1. First Bottleneck. The Licensing Moat

The regulatory authorities; the national authorities responsible for nuclear safety are the first challenge at the EU level. It is very likely that these authorities are going to struggle to approve the designs for many reasons, provoking delays and cost increases. In this environment, the licensee will suffer double alongside the regulator and could create a market barrier to entry so high that only the most well-capitalised first-movers survive.

In this line, the **fragmentation of the EU nuclear regulatory framework** creates a unique disadvantage not shared by other markets like the USA or China. Nuclear licensing is entirely national, with each member state operating its own regulatory authority, applying its own safety standards, requiring documentation in its own language, and following its own procedural timeline. For a large national utility constructing a single reactor in one country, this system is manageable yet slow. For an SMR developer, whose business model depends on deploying standardised units across multiple jurisdictions (the very feature that makes the modular approach economically attractive) this framework is structurally prohibitive. Reactor vendors must often modify their designs substantially from country to country, incurring considerable costs and delays to comply with diverse national legislation.[7]

In Europe, adaptation costs of country-to-country can add up to **30% of a plant's total engineering and construction costs**[8]. While China and Russia have already operationalised SMRs by giving their national regulators the power to build under special provisions, the EU's fragmented approach leads to **duplicated efforts**.

This fragmentation is reflected in the **size and capacity of regulatory authorities**. While the US NRC and major Asian regulators operate on a massive, centralised scale with thousands of experts, many EU national authorities lack the suitably qualified and experienced personnel to assess non-conventional SMRs, like molten salt or liquid metal designs. The UK's ONR, for instance, employs over 600 staff, but even at this size, it faces a **shortage of scientific expertise** that leads to overly cautious, risk-averse decisions that further delay project delivery.

Table 1 illustrates the scale of this divergence. The US stands apart as the only jurisdiction with a dedicated SMR licensing track, provisions for factory certification of modular components, and a performance-based regulatory approach, all administered by a single national authority. The result is an estimated licensing timeline of three to five years for a certified design. At the other end of the spectrum, Member States without an established nuclear licensing infrastructure face indicative timelines of ten to fifteen years, with no adapted fee structures, no modular certification pathway, and no SMR-specific procedural track. Even within the EU's more experienced nuclear states, such as France, Finland, and Czechia, SMR-specific provisions either remain absent or only partially developed.

The practical consequence is that an SMR developer seeking to deploy the same standardised unit across five European markets faces, in effect, five separate and largely non-overlapping licensing processes each with its own do-

7 S. Rohunsingh, T. Sainati, B. Hanson, and R. Kay (2023). 'Licensing small modular reactors: a state-of-the-art review of the challenges and barriers'. *Progress in Nuclear Energy*, 164, 104859. https://doi.org/10.1016/j.pnucene.2023.104859

8 OECD Nuclear Energy Agency (2020). *Unlocking Reductions in the Construction Costs of Nuclear*. Paris: OECD NEA; World Economic Forum (2023). *Framework to Accelerate the Deployment of Advanced Nuclear and Small Modular Reactors*. Geneva: WEF.

cumentation requirements, procedural stages, and administrative timeline. The resulting cost premium is substantial. As noted above, regulatory adaptation costs account for up to 30% of total engineering[9] and construction expenditure. For a technology whose economic case depends on standardisation and replication, this represents an unmanageable transaction cost and constitutes a major structural barrier to the business model itself.

**Table 3.** Regulatory and Licensing Frameworks for SMRs – Selected Jurisdictions

| Regulatory feature | United States | France | England | Czechia | EU (no nuclear tradition)* |
|---|---|---|---|---|---|
| Single national licensing authority | ✓ | ✓ | ✓ | ✓ | ✕ |
| SMR-specific licensing track | ✓[1] | partial | ✕ | ✕ | ✕ |
| Factory/modular certification provisions | ✓[1] | partial[2] | ✕ | ✕ | ✕ |
| Performance-based (goal-setting) approach | ✓[1] | partial[2] | ✕ | ✕ | ✕ |
| International regulatory cooperation | ✓ | ✓ | ✓ | partial | partial |
| Estimated licensing timeline (years) | 3-5[1] | 5-7[2] | 7-10[3] | 8-12[3] | 10-15[3] |
| Regulatory fee structure adapted for SMRs | partial[1] | ✕ | ✕ | ✕ | ✕ |

✓ = in place, partial = under development or partially implemented, X = not in place.

* Representative of member states without established nuclear licensing infrastructure (e.g. Austria, Portugal, Denmark).

**Note on timeline estimates**: Licensing timeline figures are indicative ranges drawn from the literature and reflect the full process from design certification application to construction licence, under current regulatory conditions. They do not account for pre-application engagement periods, which can add 1–3 years in most jurisdictions. The US range of 3–5 years reflects the NRC's Part 52 com-

9 UK Nuclear Regulatory Review 2025

bined licence process for certified designs; the EU ranges reflect historical experience with large reactor licensing adapted for SMR-scale projects, in the absence of dedicated SMR tracks. Based on various sources: [1] US Nuclear Regulatory Commission (2023), Licensing New Nuclear Power Plants; Rohunsingh et al. (2023), 'Licensing SMRs', Progress in Nuclear Energy, 164, 104859. [2] Eurelectric (2020), Unlocking the Potential of SMRs in the EU; OECD NEA (2021), SMRs: Challenges and Opportunities. [3] Rohunsingh et al. (2023); Fernández Cosials & Saravakos (2025), 'Core regulatory barriers to SMRs', in Fernández Ordóñez (ed.), SMRs: Europe's Energy Future, ELF, pp. 27–31.

Another main reason that will prevent the SMR market from flourishing is the fundamental principle that, since the 1970s, most EU regulators rely on. In the EU, mostly all regulators adhere to the safety principle regarding radioactive dose, named ALARA[10] (see Directive 96/29/Euratom).

*ALARA (As Low As Reasonably Achievable)*

In theory, this rule was intended to optimise general safety given the uncertainties associated with radiation effects knowledge. The principle requires that radioactive dose generated by the plant and received by the workers or public must be As Low As Reasonably Achievable. It is in line with the principle of precaution of the EU, enshrined in Article 191 of the Treaty on the Functioning of the European Union (TFEU), which mandates a proactive approach to risk management, particularly in environmental policy.

By taking a close look at the "R" from ALARA -reasonably-, in an engineering field, it can be foreseen that it is going to generate disagreements. In practice, the "R" means that ALARA can be interpreted expansively, creating pressure for continual marginal reductions even where residual risk is already minimal.

This effectively means that unless nuclear electricity is as expensive as its competitors are, this is, if nuclear energy still has profits not used in reducing the radiation doses to workers, then if the regulator is following ALARA, they are not seen as doing their job. In practical terms, it has become an **explicit mandate of the regulatory system to increase costs** to the point where nuclear power is barely economic. This creates a **"regulatory ratchet"** where any tech-

10 Other variations include ALARP (As Low as Reasonably Practicable).

nological advancement that makes a design cheaper or safer simply provides more "room" to drive costs back up through new requirements[11,12].

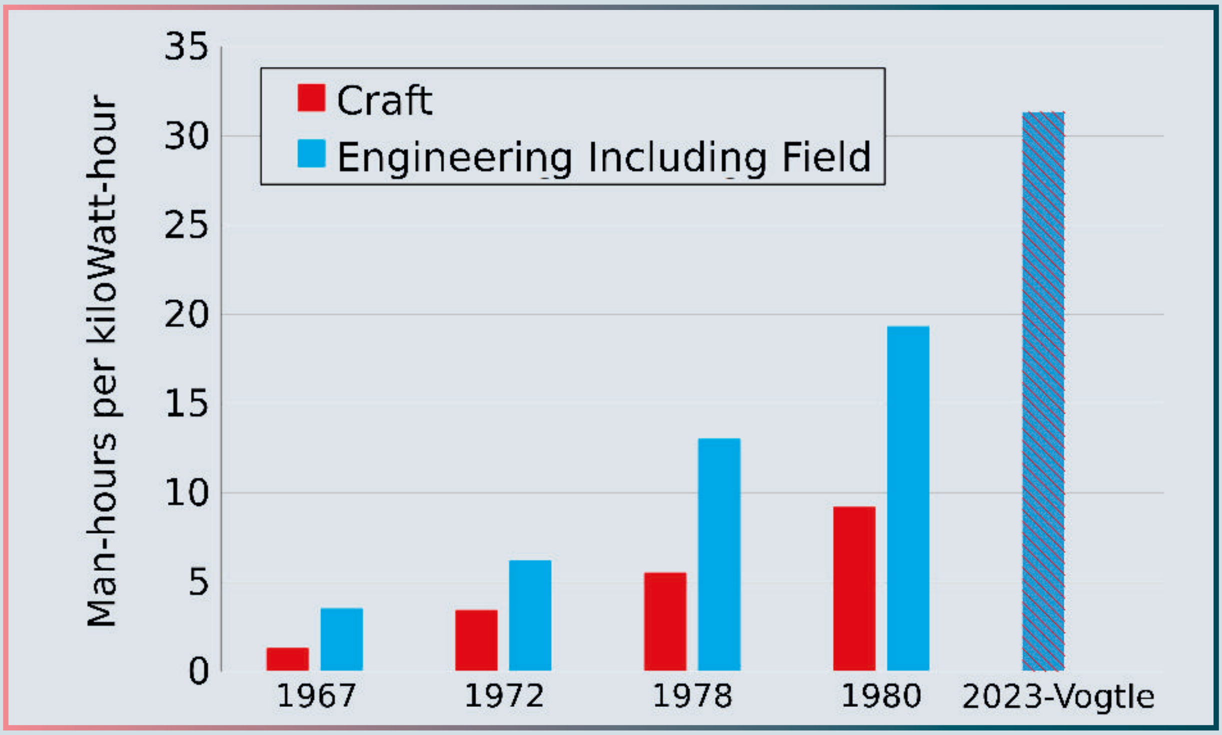
For an SMR developer, ALARA is a **serious challenge** because no engineer can design for a standard that has no fixed limit, and no rational investor wants exposure to a system where the rules can change as soon as the SMR design shows a profit. If a new technology is inherently more efficient, ALARA mandates that this efficiency be "taxed" in the form of additional safety layers. As a consequence of that, this philosophy essentially promotes radio-phobia to the general public by implying that near-background dose rates are perilous, creating a vicious circle where increased spending on protection leads to greater public concern, which then demands even more spending.

On top of that, the sheer quantity of **paperwork** now required under the ALARA standard has become a paralysing force. Modern nuclear projects are struck by a documentation ratio where **paperwork hours outnumber real labour hours** by at least two-to-one. The 2025 UK Regulatory Review diagnosed this as a systemic failure where "process trumps outcomes,", or a **prioritising of process over result;** allowing complex procedures to be used as a protective shield for regulators and duty holders to avoid accountability. Some licence applications now generate more than **90,000 pages of documentation**, a volume so vast that a single planning officer would require nearly 400 working days just to read it.[13]

Based on historical data, see Figure 3, the escalation of labour employed in nuclear construction shows a staggering trend. In 1967, the total labour required was **4.8 man-hours/kW** (1.3 engineering, 3.5 craft); by 1980, this had ballooned to **28.5 man-hours/kW**, with engineering hours alone (9.2) nearly tripling the total labour of a decade prior. Latest data from the US of 2023 Vogtle NPP estimate the total amount to around **32 man-hours/kW**. If this trajectory continues, the man-hours required for a First If a Kind (FOAK) SMR would be astronomical, reflecting a system that has lost all connection to construction efficiency in favour of academic analytical techniques.

11 J. Devanney, 2025. *We can make Nuclear Cheap again*. *ISBN*-13. 979-8316168378.
12 Crowley et al. 1981. Energy Economic Data Base (EEDB) Program. Phase III. Final report and third update.
13 Policy Paper: 2023, Getting Great Britain building again: Speeding up infrastructure delivery.

**Figure 3.** Nuclear Power Plant Labour
1967-1980 estimates[14] with Vogtle NPP inclusion[15]




The sheer difficulty of securing a licence creates a "stickiness" that stifles the market. Countries are likely to remain tethered to the first design approved by their national regulator for decades, creating de-facto monopolies that preclude the consumer choice promised by SMR advocates.

Examples of this lockdown can be seen within the EU. The cost and time required to license a second technology were so prohibitive that, among other reasons, **Romania** found itself tethered to the **CANDU** design (a design from Canada that does not use regular water but a heavy water as moderator) for nearly 40 years simply because the institutional and regulatory momentum for a different technology could not be overcome.

This contrast with **Spain,** which represents a positive historical example of **diversification**, maintaining a fleet that includes both Pressurised Water Reactors (PWR) from different vendors, and Boiling Water Reactors (BWR), which allowed

14 Economics Of Nuclear Power: Past Record, Present Trends And Future Prospects (1985). Doal L. Phung.
15 Ibid.

for a more resilient domestic supply chain and avoided total dependency on a single vendor's design evolution. However, in the current high-cost regulatory environment, such diversification is becoming a luxury that few nations can afford to repeat.

## 2.2. Second Bottleneck: The Financial Instruments coupled to the Public Opinion

Even though SMRs reduce extensively the amount of capital required to function relative to large reactors, their financing needs require private capital to join the venture. In this respect, private capital remains cautious about SMRs. While there have been some recent developments, investors are not yet fully convinced.[16] On the other side, traditional banking will likely only favour projects that are already licensed, yet FOAK projects still require massive state subsidies or guarantees to reach that stage. As mentioned in the introduction chapter, recent large-scale nuclear projects have demonstrated **systematic capital risk exposure**, with costs escalating from €3–5 billion to well above €10–50 billion in cases such as Olkiluoto-3, Flamanville-3, and Hinckley Point C, ultimately requiring strong state intervention or regulated revenue models to remain viable. As a result, governments increasingly rely on instruments such as Contracts-for-Difference (CfD), regulated asset base (RAB) models, or even **zero-interest sovereign loans**, as currently explored in France for a €50+ billion reactor programme. These mechanisms effectively socialise early-stage risks, reflecting a structural mismatch between nuclear project risk profiles and private-sector return expectations, where capital costs alone can account for **70–80% of total electricity generation costs.**

This may create a financing paradox or an "chicken-and-egg" problem: private investors wait for proven, de-risked Nth-of-a-Kind (NOAK) projects, while NOAK status itself cannot be reached without sustained public backing of FOAK deployments.

Furthermore, these public financial instruments must convince public opinion, the most delicate and volatile variable in nuclear policy. Empirical data shows that public acceptance remains highly conditional: support for nuclear energy

16 See for example the SMR NuScale stock evolution.

can exceed 60–70% in some countries, yet opposition remains significant and highly sensitive to cost overruns, safety concerns, and waste management narratives. Critically, polling and policy analyses indicate that **cost containment and electricity price impacts are decisive factors** for maintaining public support for new nuclear programs[17]. In liberalised electricity markets, where risks are no longer absorbed by regulated monopolies, this translates into a political constraint: any perception that SMRs rely on disproportionate subsidies or unresolved waste liabilities can rapidly erode public backing and, by extension, derail state-aid approvals.

## 2.3. Third Bottleneck. The Supply Chain Constraint

**SMRs are not smartphone apps**; they require massive physical infrastructure. To achieve NOAK economies of scale, ceteris paribus, the supply market can hardly tolerate a fragmented landscape of dozens of SMRs designs. Realistically, the current global supply chain could only support a handful of winners, leading back towards a concentrated, non-competitive market. Each design implies different fuel types, supply chains, qualification pathways, nuclear stamps and component specifications; many of which (notably advanced fuels) are **not yet available at commercial scale for most of SMRs concepts.** Given the capital intensity of nuclear supply chains: heavy forgings, nuclear-grade components, fuel fabrication, and licensed engineering ecosystems, supplier networks may not economically qualify and maintain parallel production lines for dozens of competing designs. The result may be a Darwinian industrial filtering process: early movers that secure order books and supply chain commitments will lock in economies of repetition, while late or niche designs could be structurally priced out.

The supply chain, also and more importantly, involves the EU nuclear workforce. The European nuclear industry workforce is facing a retirement period on which several recent workforce assessments have already raised alarms. According to the European Nuclear Education Network, more than 25% of the current nuclear workforce is expected to retire by 2035[18]. In parallel, the pipeline of new engineers and technicians is not scaling at the pace required to sustain both life extensions of existing fleets and the deployment of new builds

17 Nuclear Nation Building. Policies and pathways for scaling new reactors across Canada. 2025
18 Competence mapping at industry level. 2024, ENEN ++ project. D 6.1

such as SMRs. This creates a structural bottleneck: even if capital and licensing hurdles are resolved, there may simply not be enough qualified welders, reactor operators, fuel cycle specialists, and regulators to execute multiple parallel SMR programmes across Europe.

This constraint is further compounded by the lack of standardisation across SMR designs. Each reactor concept, whether based on light water, sodium, molten salt, or gas-cooled technologies, demands specific competencies, training programmes, and licensing expertise. In a fragmented market, this leads to duplication of training ecosystems and inefficient allocation of scarce human capital. Forecasts from European industry bodies suggest that tens of thousands of additional skilled workers will be required by 2040 just to maintain current nuclear capacity, let alone expand it.

This issue could be particularly damaging in terms of the regulatory bodies licensing capacity of non-conventional designs. Without coordinated industrial policy and design convergence, the workforce limitation risks becoming a first-order constraint, reinforcing the tendency towards a small number of dominant designs and vendors capable of concentrating both manufacturing and human expertise.

## 2.4. So... small enough to pass through?

Based on the previous arguments, it is clear that no, SMRs are not small enough. If the EU pushes hard for SMRs without any changes, it is very possible that some of those reactors will be finally built on EU soil. However, they will hardly be cheap, and they would likely only be sustained by the taxpayers, similarly (or worse) than their large-scale counterparts. A complete re-drawing of the EU legislative nuclear landscape would be needed to make SMRs not only a reality for the EU, but a *useful reality*.

"Any perception that SMRs rely on disproportionate subsidies or unresolved waste liabilities can rapidly erode public backing and, by extension, derail state-aid approvals."

# Chapter 3. Regulatory Solutions —or— What does the housing market crisis have in common with new nuclear projects?

It may seem surprising to compare housing and nuclear power, but both sectors currently illustrate the same structural problem in the EU economy. Europe has not forgotten how to build: methods, materials, and procedures have never been more advanced, but an expanding web of regulation, bureaucracy, and taxation has made even familiar projects increasingly difficult to deliver. Over time, construction has shifted from a primarily technical challenge to an overwhelmingly administrative one. The Empire State Building is going to reach 100 years since its inauguration and it took a single year to build (from March 1930 to May 1931), One World Trade Centre, took seven times more (from April 2006 to May 2013). Flammanville Unit 2 took a bit more than 6 years to build (May 1980 to March 1987) Flammanville Unit 3 almost tripled, 17 years to build (Dec 2007 to Dec 2024).

**What the housing market and nuclear energy have in common** is that both suffer from a "site-by-site" regulatory bottleneck and a "not in my backyard" (NIMBY) mentality with regards to improvements, more efficient solutions or cost-effective ones. A mentality that prioritises protecting the status quo over macro-scale societal benefits like the ones nuclear energy brings to a country. In both sectors, regulators often focus on **"micro" site-specific outcomes** rather than the meaningful "macro" outcomes required for nature recovery or energy security. This lack of portfolio-wide vision leads to a systemic failure where the pursuit of perfection for a single project prevents the delivery of critical infrastructure needed by the masses, ultimately resulting in **astronomical costs** and a "vicious cycle" of stagnation.

## 3.1. An ALARA replacement proposal

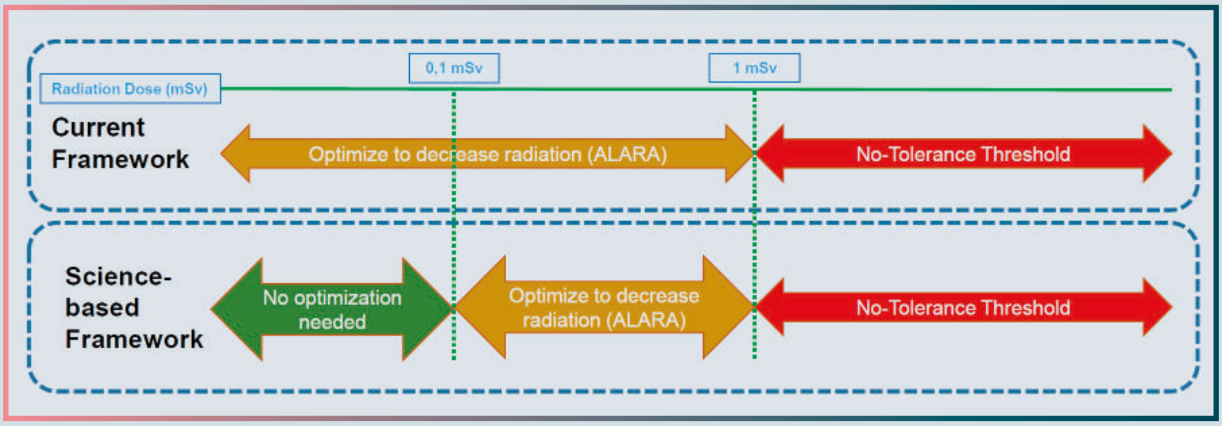
As mentioned in Chapter 2, ALARA acceptance in regulation have some consequences for SMRs. First, innovation risks stagnation. If regulatory requirements systematically escalate with each incremental safety improvement, there is little incentive to develop designs that are cheaper or inherently safer. In such a framework, technological progress does not translate into economic advantage. Rational investors will not commit capital to FOAK designs if the regulatory environment absorbs the benefits of innovation through additional cost layers.

Second, under a strict interpretation of the ALARA principle, nuclear power risks being structurally disadvantaged on cost. Because the principle encourages continuous dose reduction—even at very low exposure levels—it can drive persistent cost increases without commensurate societal benefit. In such conditions, nuclear energy struggles to become the lowest-cost option, which in turn constrains large-scale electrification of transport and industry. This disproportionately affects lower-income populations, for whom energy affordability is critical, and ultimately complicates the achievement of net-zero objectives.

Finally, a key limitation of cost-escalating regulatory frameworks is that they are asymmetric in their evolution. As mentioned, they tend to ratchet costs upward but do not adjust downward in response to external market changes. Historical evidence illustrates this dynamic. During the 1970s, fossil fuel prices surged, and nuclear costs increased in parallel, partly due to tightening regulatory requirements. However, from the 1980s onward, the real cost of coal-fired generation declined significantly, while nuclear costs remained elevated. This asymmetry contributed to the stagnation of new nuclear construction. As a result, despite being a fundamentally low marginal-cost technology, nuclear power today can struggle to compete with alternatives such as natural gas in certain markets; an outcome that reflects regulatory and market distortions rather than intrinsic economic fundamentals. If the current interpretation of ALARA is to be reconsidered in the context of SMRs**, a credible alternative framework will be required**.

The replacement of such radiation-based would need to be based on grounded science, also called science-based regulation. To do so, a**rticle 191 of the TFEU could be reviewed** and its implementation re-verified, to account for this challenging approach to safety in energy systems. Article 191 adheres to proactive regulation and the precautionary principle which embodies the ALARA thesis. In this line, other western countries outside the EU have already started to replace this standard, like the US[19]. Alternatives are being proposed like the traffic-light approach[20] , see Figure 4, or the "As High As Relatively Safe" (AHARS) standard[21]. These regulations ensure that nuclear power is not punished by an extremely conservative approach. Nuclear regulation is solely authority of each country, but it may be the shift of a single country and abandon ALARA to snowball and turn the EU table in nuclear favour.

**Figure 4.** A possible modification of ALARA to permit SMRs flourishing[22]




## 3.2. Proactive and Reactive; Risk-Informed and Performance-Based Regulations

Regulation should aim to balance risk and benefit. The traditional approach—often described as *reactive regulation*—seeks to internalise externalities by ensuring that those who generate risk bear the cost of the harm imposed on third parties. This framework underpins the governance of many beneficial yet hazardous activities, including maritime transport and high-pressure steam systems, both of which have played a transformative role in economic development. In the energy sector, the societal benefits of reliable and affordable electricity are similarly substantial. The alternative is the so-called *proactive regulation*, in which the regulation needs to anticipate the techno-

19 See US Executive Order 14300 of 23 May 2025. "Ordering the Reform of the Nuclear Regulatory Commission".
20 Völkle, H. 2026. Health Physics 130(4). *Do We Need the LNT Hypothesis in Radiation Protection? Could a Traffic Light Model Be a Practicable Solution?*
21 Wade Allison. 2009 Radiation and Reason . ISBN: 0956275613.
22 Ibid.

logical progress to provide rules and norms before mass adoption. This kind of regulation is what the precautionary principle adheres to, in line with Article 191 of TEFU.

An example of changes in regulatory approaches taken outside the EU is the US, where they have made significant progress with **Risk-Informed Regulation** through initiatives like **10 CFR Part 53**[23] and the Regulatory Guide 1.233. This framework moves away from rigid, prescriptive rules designed for large light-water nuclear reactors and instead uses a **technology-inclusive performance-based methodology**. A 2025 US Executive Order further emphasised this shift, ordering the reform of the NRC to accelerate nuclear deployment by ensuring regulation is **proportionate to actual risk** and facilitates the entry of new reactor technologies. This approach should be nonetheless adopted by each individual Member State.

## 3.3. A de-fragmentation proposal for the EU (European-Generic Design Application)

The regulatory fragmentation issue in the EU is so patent that some efforts are already taking place to address it. Small steps are seen with the EU project HARMONISE[24], of 2.5 M€. This project looks more like an attempt to force a one-size-fits-all nuclear rulebook than a genuinely practical solution. At an international level, the IAEA NHSI project has the same ambitions. They are framed as an effort to align licensing procedures and safety standards for future fission and fusion reactors. However, it seeks to do so by accommodating all existing regulatory approaches, an ambition that risks becoming overly complex. While this represents a step in the right direction, it remains largely analytical rather than actionoriented. Given the pace at which industrial and geopolitical conditions are evolving, the window for meaningful regulatory reform may be considerably shorter than these projects timeframe.

An example of EU regulatory collaboration is seen within the EAGLES consortium25. The EAGLES agreement is a cooperation deal that created the EAGLES

23 Title 10 of the US *Code of Federal Regulations* Part 53 – Risk-Informed, Technology-Inclusive Regulatory Framework for Commercial Nuclear Plants.
24 https://www.lei.lt/en/projektas/harmonise/. Project from 2022 to 2025.
25 IAEA And Eagles Launch First International Pre-Licensing Project For Lead-Cooled Small Modular Reactors

Consortium to develop and commercialise EAGLES-300, a next-generation lead-cooled SMR. The agreement formalises collaboration among European nuclear organisations to share R&D, coordinate engineering work, and avoid duplicating effort. The countries that have agreed to work together on the EAGLES pre-licensing effort are Belgium, Italy, and Romania. Their regulators signed on to a joint pre-licensing initiative for the EAGLES-300 lead-cooled reactor, with the goal of aligning regulatory requirements before formal licensing. Other examples of similar ventures include the Nuward and the BWRX-300 designs. Relevant actors like the "Renew Europe" group are proposing this kind of approach[26].

Nonetheless, a common outcome of this collaboration efforts can be summarised on "*Regulators agree on safety, but they disagree on syntax*". This is, nuclear energy regulators have similar goals and commitments across the EU. But procedures, interactions and also syntax prevents sometimes for a common agreement. Apparently, making all EU regulators agree on syntax is a Sisyphus task.

> "The EU may be suffering from an over-expanding regulation effort in many fields, but this weakness can be turned into a strength."

Close to the EU, the UK is proposing the Generic Design Assessment (GDA)[27] which provide a blueprint for this transition by allowing for site-independent design reviews. An obtained GDA does not mean construction can start; it is a "generic" approval. Developers must still obtain a **nuclear site licence, environmental permits,** and **planning permission** (a development consent order) for a specific location. Some SMRs in the UK are being licensed using this approach, like Rolls Royce SMR, HOLTEC-300 or Hitachi BWRX-300. The idea was that completing the GDA significantly reduces commercial risk by providing regulatory certainty before billions are spent on a specific site; nonetheless, this UK GDA has shown to be not flexible enough[28].

(SMRs). In https://www.eagles300.com/

26 Position Paper Small and Advanced Modular Reactors. 2026. https://reneweuropegroup.app.box.com/s/p5p87bas0aba4zbwyslr5hhx5y2b446c

27 Generic Design Assessment (GDA) in https://www.onr.org.uk/generic-design-assessment

28 According to John Fingleton and his "UK Nuclear Regulatory Review 2025"

For this reason, the first proposal is the development of a **European-General Design Application (EU-GDA).** If regulatory authorities across European countries agree to validate an EU-GDA issued by any other regulatory authority, it would formalise this by acting as a "one-stop shop" for design certification across the continent. This body would allow for **mutual recognition** of regulatory decisions among Member States, ensuring that if a trusted regulator has already thoroughly assessed a design or component, that work is leveraged rather than repeated.

The EU-GDA would prioritise **standardisation**, allowing SMRs to be factory-fabricated and deployed across different territories without significant modification. By establishing an "SMR coalition" of the willing, the EU could align its territories under common safety and environmental benchmarks, providing the **regulatory certainty** required to attract substantial private capital and shorten the path to commercialisation by the early 2030s.

An even more ambitious proposal would be to include the so-called "Reliance Clause" for nuclear regulators. This approach consist of trusting other countries' regulators as if they were their Technical Support Organisation (TSO). TSOs are external companies that normally help the regulators with their licence applications, their supervision and any other work. It could be argued that the best TSO for a regulator would be indeed another country's regulator. Within this approach, in the course of licensing proceedings, the regulatory authority may consider the results of safety assessments, analyses, tests or opinions conducted by competent regulatory bodies of other EU states. They may recognise other countries' design approval as evidence of safety requirements and waive (whole or in part) their own analyses. With this approach each **Member State sovereignty** is fully guaranteed and unchanged within the EU, but it will become ***"the power to decide, not the obligation to duplicate"***[29]. The EU may be suffering from an over-expanding regulation effort in many fields, but this weakness can be turned into a strength. **If the EU decides to pool their regulatory authority resources, they will become a worldwide nuclear regulatory powerhouse**, who could streamline SMRs licensing applications faster than other markets with a smaller regulatory size (such as US or China).

29 Workshop: "SMR/AMR regulation aspects." 2026. Spring Meeting of the High Scientific Council of the ENS.

## 3.4. Forging a free market approach to nuclear regulation of SMRs

Given that the nuclear industry has historically remained closely tied to a state-centric model, extensive public-sector involvement has been treated as the default, while transitions towards more market-oriented governance structures have been limited. This contrasts with other sectors that involve beneficial yet hazardous activities with long-term risk exposure, where risk management is largely mediated through market mechanisms operating under a legal framework.

A central feature of these sectors is not only the presence of a regulator, but **the mandatory role of insurance**. Operators of risky activities are required to carry liability coverage sufficient to compensate third parties in the event of harm. The availability and pricing of such insurance are directly linked to the insurer's assessment of operational risk. In effect, this embeds the cost of potential harm into the operator's economic decision-making. Provided that liability caps and compensation frameworks are appropriately calibrated, this mechanism can approximate a socially efficient balance between risk and benefit. Importantly, for activities that are both highly beneficial and inherently hazardous, the optimal balance never corresponds to zero risk. If a nuclear installation loses its insurance coverage and is unable to secure a replacement, this would constitute a clear signal that the plant no longer meets acceptable risk thresholds. In such cases, national authorities would be required to suspend operations.

This model also offers a degree of resilience to public and political pressure following adverse events. In the case of an incident, victims are compensated through established liability mechanisms, while cases of negligence may trigger additional legal sanctions.

Integrating the insurance sector more centrally into nuclear oversight could strengthen this dynamic. Insurers already perform detailed risk assessments, as their financial exposure depends on accurately pricing and managing risk. If a developer cannot demonstrate to an underwriter that a project meets acceptable safety thresholds at a viable premium, the project will not proceed. This creates a powerful, continuous incentive for safety that operates alongside formal regulation. In this sense, insurance functions as a form of decentralised, market-based supervision.

Within the EU, nuclear installations are already subject to mandatory liability insurance frameworks[30], notably under the Paris Convention on Third Party Liability in the Field of Nuclear Energy and the Vienna Convention on Civil Liability for Nuclear Damage. However, the risk assessment role of insurers is only partially leveraged, as it overlaps with—and is often secondary to—the role of nuclear regulatory authorities. Both institutions evaluate safety conditions, but their efforts are not fully integrated.

As a proposal, a potential evolution would be to more **explicitly incorporate insurers into the supervisory ecosystem**, using them as complementary or, in agreed areas, proxy agents for regulatory oversight. This could reduce the administrative burden on public authorities while preserving, or even enhancing, safety outcomes through continuous, economically grounded risk evaluation.

To address financial barriers, particularly for smaller Member States, **a European Mandatory Nuclear Insurance Fund** could be established to reinforce and partially harmonise existing liability frameworks, similar to what will be explained in Chapter 4.

The determination of insurance premiums would introduce a complementary institutional actor: nuclear safety certification agencies. These entities would assume part of the technical assessment currently performed by regulators. The adoption of **Certification Agencies in the EU nuclear field**, which could be modelled on the Classification Society system used in shipping (e.g., ABS, Bureau Veritas, TÜV), would simplify and accelerate any permission process. They will be complementing the supervision and licensing processes in the current state and will ease the work of regulatory authorities. Regulatory authorities regularly rely already on external Technical Support Organisations (TSO) for their work on licence applications or other workloads. Those certification agencies are supposed to serve as TSO for both the insurers and the regulatory authorities.

However, a key feature of the model is competition. The nuclear certification societies must compete for NPP owners. This sets up a balancing mechanism:

30 https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/liability-for-nuclear-damage

If a certification society is too strict, it loses business. At the same time, credibility constraints would discipline the system; if a certification society was overly permissive, its certification would lose recognition from insurers and will not be accepted.

These agencies would prioritise outcome-based criteria, focusing on scientifically grounded dose limits and system-level performance, rather than prescriptive process compliance. This approach encourages **real safety competition** between vendors, as they are rewarded for outcomes rather than "excellent process adherence". This radical shift would free the sector from the standard of regulatory inflation, allowing nuclear power to reach the lowest electricity cost, as it historically has proved itself to be capable of.

For this proposal to function effectively, the EU should actively promote competition across all relevant layers of the system: insurance underwriting, safety certification, and reactor supply. Barriers to entry for insurers and certification bodies should be reduced while consistent with financial and technical robustness, in order to avoid excessive market concentration. The viability of the model depends on meaningful competition; a market with only a small number of certification agencies or insurers would risk inefficiencies, reduced credibility, and potential regulatory capture. In this context, rigorous application of EU competition policy, including antitrust and anti–price-fixing provisions, would be essential.

Within this architecture, regulatory authorities would retain a critical, though more focused, role. They would continue to oversee NPPs but could concentrate on establishing and enforcing safety boundary conditions and complement certification agencies reports. Their responsibilities would still include setting limits on environmental contamination, defining dose-rate thresholds, and establishing radiological monitoring requirements around nuclear facilities.

# Chapter 4. Financial Solutions; Unlocking Private Capital for Small Modular Reactors in Europe: A Market-Based Framework for Financing and Risk Allocation

## 4.1. Reframing the Problem: Risk, Not Capital Scarcity

Despite growing political interest, a substantial pipeline of design certifications, and genuine private-sector enthusiasm, SMR deployment in Europe remains largely a theoretical prospect. As previously mentioned, one major constraint is financial: **new nuclear energy projects are perceived as expensive**, with very high upfront capital requirements, and private investors are often unwilling to bear the associated risks. This framing, however, confuses the symptom with the underlying challenge. There is no general scarcity of capital that would prevent the construction of SMRs. Global infrastructure funds, pension funds, and long-duration asset managers are actively seeking stable, long-term, low-correlation returns of precisely the type that a mature energy infrastructure asset can provide.[31] The challenge, however, is that SMRs do not currently constitute such an asset. For investors, they represent a bundle of overlapping risks (technological, regulatory, political, and contractual) that no market actor has yet been able to price and allocate with sufficient confidence.

The distinction has significant implications for policy design. A capital-scarcity diagnosis points towards public subsidies and guaranteed returns, interventions that are costly, politically contested, and often counterproductive when they substitute for rather than complement market incentives. By contrast, a risk-allocation diagnosis calls for a very different set of tools: institutional reform, standardisation, long-term contracting, and the targeted use of public instruments to address distortions generated by the policy environment itself.

31 OECD Nuclear Energy Agency (2022). *The Challenges and Opportunities in Financing Small Modular Nuclear Reactors*. Paris: OECD NEA. https://www.oecd-nea.org/jcms/pl_59235

This section argues that the second diagnosis is more accurate and develops a financing framework based on its implications.[32]

## 4.2. Institutional Preconditions: What Markets Actually Need

Before discussing financial instruments, it is necessary to clarify what makes an infrastructure asset investable. Both academic and practitioner literature converge on a consistent set of factors, including long-term revenue visibility, predictable operating costs, a stable legal and regulatory environment, and the absence of retroactive policy changes.[33] Nuclear energy and SMRs in particular, perform poorly on several of these dimensions, not due to intrinsic technological limitations, but because of the institutional environment in which they operate. It is this environment that creates the problem in the first place.

The most consequential institutional barrier as mentioned in Chapter 3.1 in Europe is regulatory fragmentation.[34] The cost implications are severe. Without regulatory provisions that allow for the certification of integral components during manufacture, the efficiency gains and cost reductions promised by modularity can be severely undermined.

An approach broadly analogous to how the European Aviation Safety Agency operates for aircraft type certification, a precedent demonstrating that the model is both legally and institutionally achievable[35] would be required. Pre-feasibility assessments have already identified strong global demand, potentia-

32 The framing of institutional risk as the primary barrier to nuclear investment draws on the broader infrastructure finance literature; see particularly E.R. Yescombe (2014). *Principles of Project Finance* (2nd edn). Oxford: Academic Press.
33 J. Stern (2007). 'The British utility regulation model: its recent history and future prospects'. *Journal of Regulatory Economics*, 31(3), 253–275; R.G. Newell, R.G., & Pizer, W.A. (2003). 'Discounting the distant future: how much do uncertain rates increase valuations?'. *Journal of Environmental Economics and Management*, 46(1), 52–71. Newell and W.A. Pizer (2003). 'Discounting the distant future: how much do uncertain rates increase valuations?'. *Journal of Environmental Economics and Management*, 46(1), 52–71.
34 S. Rohunsingh, T. Sainati, B. Hanson, and R. Kay (2023). 'Licensing small modular reactors: a state-of-the-art review of the challenges and barriers'. *Progress in Nuclear Energy*, 164, 104859. https://doi.org/10.1016/j.pnucene.2023.104859
35 B. Mignacca and G. Locatelli (2019). 'Economics and finance of Small Modular Reactors: a systematic review and research agenda'. *Renewable and Sustainable Energy Reviews*, 118, 109519. https://doi.org/10.1016/j.rser.2019.109519; International Energy Agency (2020). *Projected Costs of Generating Electricity* (2020 edn). Paris: IEA/NEA.

lly reaching hundreds of SMRs worldwide by 2040, making early European leadership in harmonised certification a strategic industrial opportunity rather than merely a regulatory tidying exercise.

The second institutional precondition is long-term policy credibility. The cost of capital for a nuclear project, typically the single most important driver of the levelised cost of electricity, is highly sensitive to policy risk. A financing structure assembled under one regulatory and market framework can be rendered unviable overnight by a policy reversal, such as the withdrawal of a feed-in tariff, the imposition of a carbon price ceiling, or a government decision to exit nuclear energy. Germany's Energiewende (long-term energy transition policy), whatever its broader merits, destroyed billions of euros in asset value and demonstrated to long-horizon investors across Europe what policy instability looks like in practice. The current EU taxonomy framework, despite its 'transitional' acknowledgment of nuclear fission, continues to suffer from political contestation and a lack of long-term clarity, with state aid eligibility and access to green finance remaining grey areas subject to considerable political pressure. This regulatory ambiguity deters private investment by increasing policy risk, particularly in countries with volatile political attitudes towards nuclear power.

> "Reducing the cost of capital for nuclear investment through regulatory certainty, long-term revenue contracts, and targeted risk-sharing is not merely a financing preference. It is the single most powerful lever for making SMRs economically competitive."

Figure 5 demonstrates that nuclear energy is uniquely sensitive to the cost of capital among baseload technologies. As the IEA/NEA source confirms, nuclear's Levelised Cost of Electricity (LCOE)[36] curve rises far more steeply with the discount rate than either coal or gas, reflecting its high upfront capital intensity and long construction timeline, which front-load costs decades before the asset generates revenue.

The policy implication is direct. Reducing the cost of capital for nuclear investment through regulatory certainty, long-term revenue contracts, and targeted risk-sharing is not merely a financing preference. It is the single most powerful lever for making SMRs economically competitive. A five-percentage-point reduction in the discount rate achieves a cost reduction that no engineering improvement or supply chain optimisation could plausibly match in the near term. This is why the institutional preconditions discussed in this chapter are not peripheral to the SMR financing question; they are central to it.

**Figure 5.** Sensitivity of Nuclear LCOE to Weighted Average Cost of Capital at Different Discount Rates


**Source:** IEA/NEA (2020). Projected Costs of Generating Electricity. Paris: IEA/NEA. Figure ES5 (p. 18) and Table 3.22a (p. 72). Values at 50% capacity factor, new build.

36 LCOE measures the average cost per unit of electricity generated over a plant's lifetime, expressed in USD per megawatt-hour.

Credibility of this kind cannot be created by political declaration. It must be embedded in legal and contractual structures, including long-duration concessions, framework agreements with meaningful exit penalties, independent regulatory bodies insulated from ministerial direction, and clear legislative commitments to carbon pricing mechanisms that do not expire or fluctuate with electoral cycles. The EU's taxonomy regulation, despite its other controversies, has at least provided a durable signal that nuclear energy is compatible with sustainable finance classification, and this matters because it affects the eligibility of nuclear assets for a significant class of institutional investors.[37]

The institutional reforms described above constitute the precondition for a specific and identifiable class of private investment that is already emerging at the edges of the European energy market. Large technology companies, facing rapidly escalating electricity demand from data centres and AI infrastructure, have a direct commercial interest in securing firm, low-carbon power at competitive long-term cost. They possess the balance sheets to sign 20-year offtake agreements, the creditworthiness to anchor project finance structures, and, critically, the strategic incentive to invest not merely in power purchase but in the development of the underlying generation capacity itself. This is not hypothetical: the Microsoft–Constellation transaction and subsequent commitments by Google and Amazon demonstrate that the demand is real and the capital is available.

## 4.3. Revenue Stabilisation Without Guaranteed Returns

Even with regulatory harmonisation and long-term policy commitments in place, SMR developers will face a revenue risk problem in electricity markets that are inherently volatile. Addressing this without resorting to open-ended state guarantees is the central financial engineering challenge of SMR deployment. The most market-compatible solution is the Power Purchase Agreement (PPA), a long-term bilateral contract between the generator and an offtaker that fixes the price of electricity over a defined period, typically 15 to 25 years. PPAs are not a novel instrument; they are standard in renewable energy

37 International Energy Agency (2024). *Electricity 2024: Analysis and Forecast to 2026*. Paris: IEA

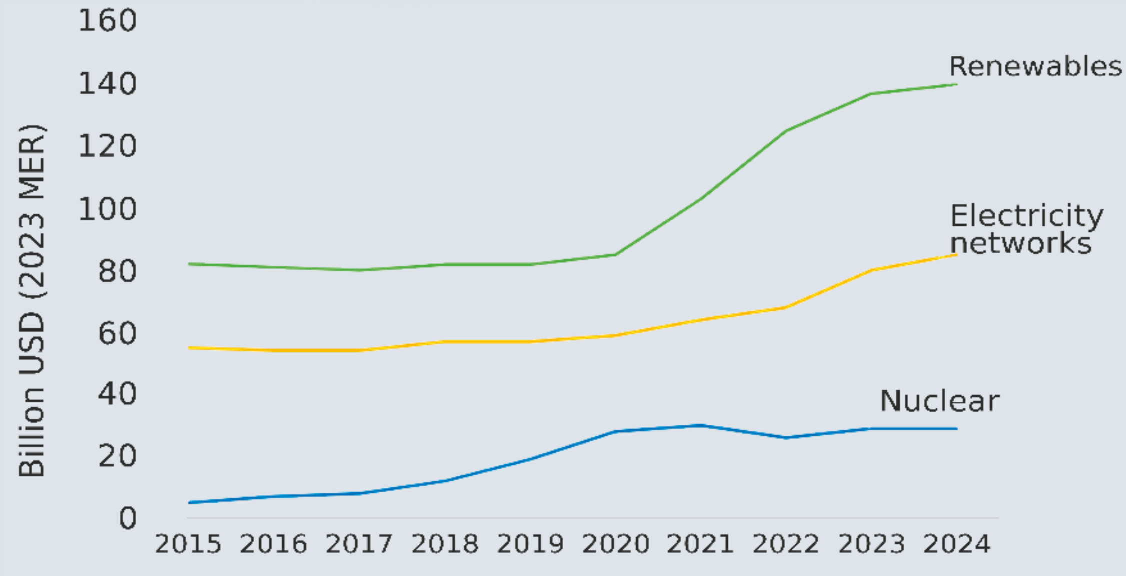
financing and are increasingly used by large industrial and technology companies to secure stable, clean power supplies. What is new is the scale and nature of the demand now emerging from the technology sector.

A data centre, for example, cannot operate on intermittent renewable power without substantial battery or grid backup. SMRs, by contrast, provide exactly what a data centre operator requires: firm, dispatchable, round-the-clock clean power with a small physical footprint and a very long operational life. Figure 6 presents annual power sector investment in Europe across three categories (nuclear, renewables, and electricity networks) from 2015 to 2024. The data tells two stories simultaneously, both of which are highly relevant to the development of SMRs as a viable energy source.

The first story is one of structural imbalance. In 2024, European investment in renewable power reached $140 billion, compared with $29 billion for nuclear, a ratio of nearly five to one. This gap has been a persistent feature of the investment landscape throughout the period: even in the best year for nuclear in the dataset (2021, at $30 billion), renewables investment stood at $103 billion. The disparity is not explained by differences in the underlying capital available to energy infrastructure; the same institutional investors who fund renewable projects are, in principle, equally capable of funding nuclear. It reflects, instead, a difference in investability, namely the extent to which each technology constitutes a financeable asset under current regulatory and contractual conditions.

The second story is more nuanced and arguably more important for the policy debate. Nuclear investment in Europe did not stagnate over the period, rising from $5 billion in 2015 to $29 billion in 2024, a nominal increase of nearly 480%. This trajectory, modest in absolute terms but directionally significant, reflects the gradual re-engagement of private and institutional capital with nuclear assets as energy security concerns intensified following 2022 and as the first SMR design certifications began to create investable project pipelines. The capital, in other words, is beginning to move, and the data suggest that nuclear energy is indeed investable; nevertheless, it remains substantially under-invested relative to its potential contribution.

**Figure 6.** Annual Power Sector Investment in Europe by Category, 2015–2024 (Billion USD)




**Source:** IEA (2024). World Energy Investment 2024.
Europe tab, rows 19–20, 23. All values in billion USD (2023, market exchange rates).

From a financing perspective, a bankable long-term PPA transforms an SMR project from a speculative development into something resembling a regulated infrastructure asset (predictable revenue, long tenor, creditworthy counterparty, and a defined cost base). This is precisely the asset class that pension funds, infrastructure funds, and insurance companies are mandated to hold. The policy implication is straightforward: European regulators should actively facilitate and standardise the PPA market for nuclear power, removing any remaining legal or regulatory ambiguities that make long-term nuclear power contracts difficult to execute or enforce across member states.

A complementary instrument is the Contract for Difference (CfD), whereby the government pays the generator the difference between a strike price and the market reference price, effectively providing a price floor without limiting upside exposure. CfDs have been used extensively in UK offshore wind financing and have been adopted for nuclear under the Regulated Asset Base model applied to Hinkley Point C and Sizewell B. Their use for SMRs is defensible under a market-based framework, but with important caveats: the strike price must be set competitively, the contract duration must be limited to the period necessary to establish market confidence in the technology, and the instrument must be explicitly structured as a transitional measure rather than a permanent feature of SMR economics. An indefinitely CfD-supported nuclear sector is not a market; it is a regulated utility.

## 4.4. Capital Market Instruments and Financial Structures

Given a stable regulatory environment and a bankable revenue contract, the full range of infrastructure capital market instruments becomes available for SMR financing. The structure of a mature SMR financing arrangement will likely resemble project finance structures familiar from large-scale infrastructure (a special purpose vehicle holding the project assets, capitalised with a mix of senior debt and equity, with revenue contracted at the project level and recourse limited to the project assets).

Project finance of this kind (non-recourse or limited-recourse) is the standard structure for infrastructure investment globally, and the investor base for it is deep. The European long-term infrastructure debt market, comprising bank lending, private placement notes, and infrastructure bonds, mobilised approximately €320 billion annually in the period 2019–2022, the majority of it for energy and transport assets.[38] The European Investment Bank, the European Bank for Reconstruction and Development, and a growing number of national promotional banks have explicit mandates to support clean energy infrastructure. These institutions can play a useful role as co-investors or guarantors for first-of-a-kind projects (where the absence of a comparable track record prevents full risk pricing by commercial markets), but their involvement should be structured to crowd in private capital rather than substitute for it.

Equity capital for SMR development is already mobilising at the pre-construction stage. Venture capital and growth equity have flowed to SMR developers including NuScale, Rolls-Royce SMR, and Kairos Power, based on the tech-

38 AFME (2023). *European Infrastructure Finance 2023*. Association for Financial Markets in Europe.

nology's long-term commercial potential rather than near-term revenue.[39] This early-stage capital performs a critical function, bearing technology and development risk that is inappropriate for debt markets. The policy challenge is to ensure that the transition from development-stage financing to project financing, the 'valley of death' between a certified design and a funded first unit, does not become a permanent obstacle. Institutional equity investors, such as infrastructure funds, sovereign wealth funds, and long-duration pension funds, are increasingly comfortable with nuclear risk at the project stage, provided that construction risk is adequately managed. This brings us to what is, in practice, the most significant financial risk in nuclear investment: not revenue uncertainty, but the history of catastrophic construction cost overruns.

## 4.5. The American Experience: A Reference Point for Limited Public Intervention

The United States provides an instructive, if imperfect, reference for the kind of limited public intervention that can catalyse private SMR investment without substituting for market discipline. The US framework has evolved through several instruments, all broadly consistent with a market-based approach.

The Price-Anderson Nuclear Industries Indemnity Act establishes a tiered liability and compensation system for nuclear incidents. Under this framework, nuclear operators are required to carry the maximum available commercial insurance, currently approximately $450 million per site. Beyond this threshold, a pooled industry fund, funded by contributions from all licensed reactor operators, provides a second tier of approximately $13 billion. Only above this combined level does the federal government's backstop come into play, and even then it is subject to congressional appropriation rather than an automatic guarantee.[40] The key features of the Price-Anderson model, which are mandatory commercial insurance, industry-funded pooling before public exposure, and a clear cap on public liability, offer a template for a European

39 World Nuclear Association (2024). *Small Nuclear Power Reactors*. Information Library. https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors

40 US Nuclear Regulatory Commission (2023). *Financial Protection Requirements and Indemnity Agreements: Price-Anderson Act*. Washington, DC: NRC. https://www.nrc.gov/about-nrc/regulatory/enforcement/price-anderson.html

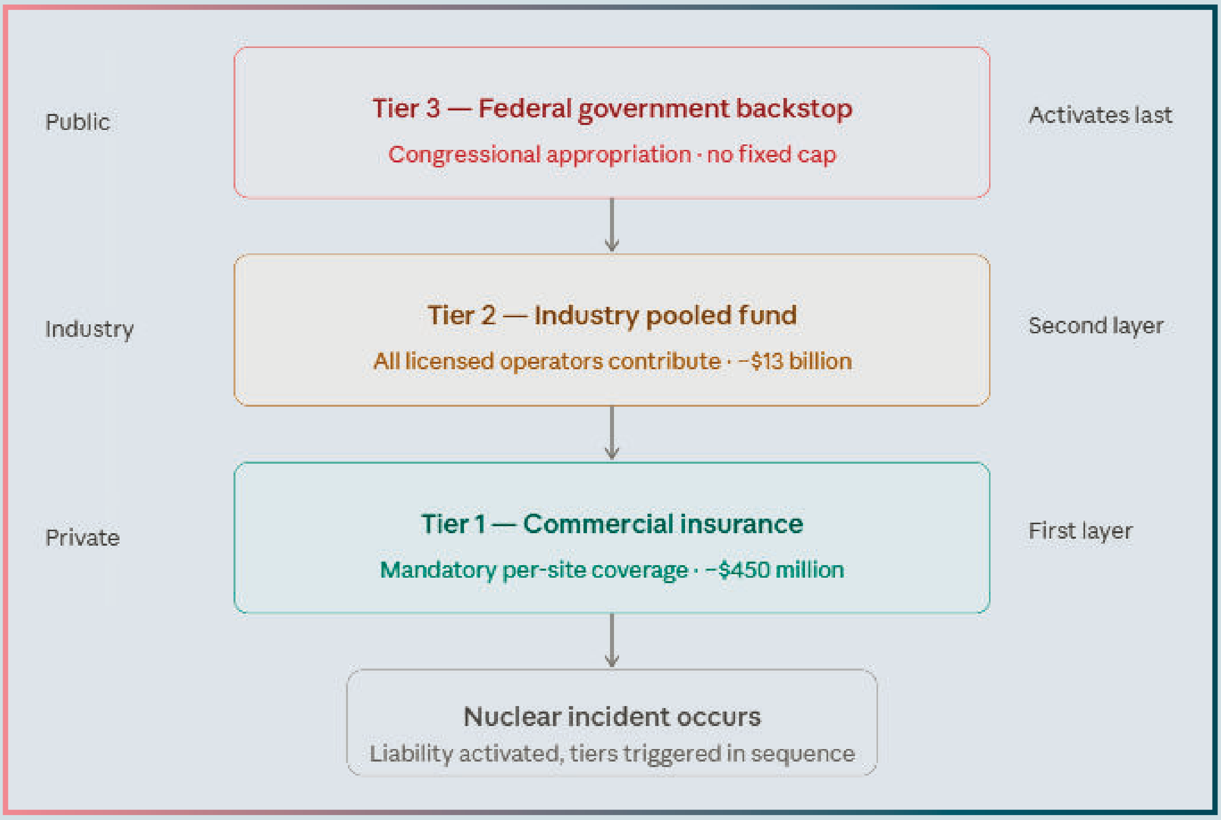
liability framework that addresses investor and public concerns without creating open-ended fiscal exposure.

Figure 7 illustrates the three-tier liability structure established under the Price-Anderson Nuclear Industries Indemnity Act, which has governed nuclear liability in the United States since 1957 and has been renewed repeatedly by Congress. The structure is deliberately layered to minimise public fiscal exposure while ensuring that compensation remains available at scale in the event of a major incident.

The first tier, the mandatory commercial insurance of approximately $450 million per licensed site, is borne entirely by the private sector and priced by the insurance market. The second tier is a pooled industry fund, to which every licensed reactor operator in the United States contributes on a retrospective basis, with the combined capacity of this fund currently standing at approximately $13 billion. Only if a nuclear incident were to generate damages exceeding both layers would the federal government's backstop come into play, and even then, congressional appropriation is required rather than automatic disbursement.

The policy significance of this structure for the SMR debate is threefold. First, it resolves the unlimited liability problem that would otherwise render nuclear investment effectively uninsurable: by capping each tier and defining the public backstop explicitly, it makes the residual risk priceable. Second, it aligns incentives within the industry: operators who contribute to the pooled fund have a direct financial interest in the safety performance of their peers, creating a form of mutual monitoring absent from a purely state-guaranteed system. Third, and most importantly for European policymakers, it demonstrates that robust liability coverage for nuclear energy does not require the state to absorb the primary risk, only to define its outer boundary. An EU adaptation of this model, calibrated to the smaller output and passive safety characteristics of SMR designs, would address one of the most persistent sources of investor uncertainty in the European nuclear financing landscape without committing public funds to routine commercial risk as also commented in Chapter 3.

**Figure 7.** Price-Anderson Liability Tiering Structure:
A Potential Model for EU Adaptation




Source: US Nuclear Regulatory Commission (2023). Financial Protection Requirements and Indemnity Agreements: Price-Anderson Act. Washington, DC: NRC. https://www.nrc.gov/reading-rm/doc-collections/cfr/part140/full-text

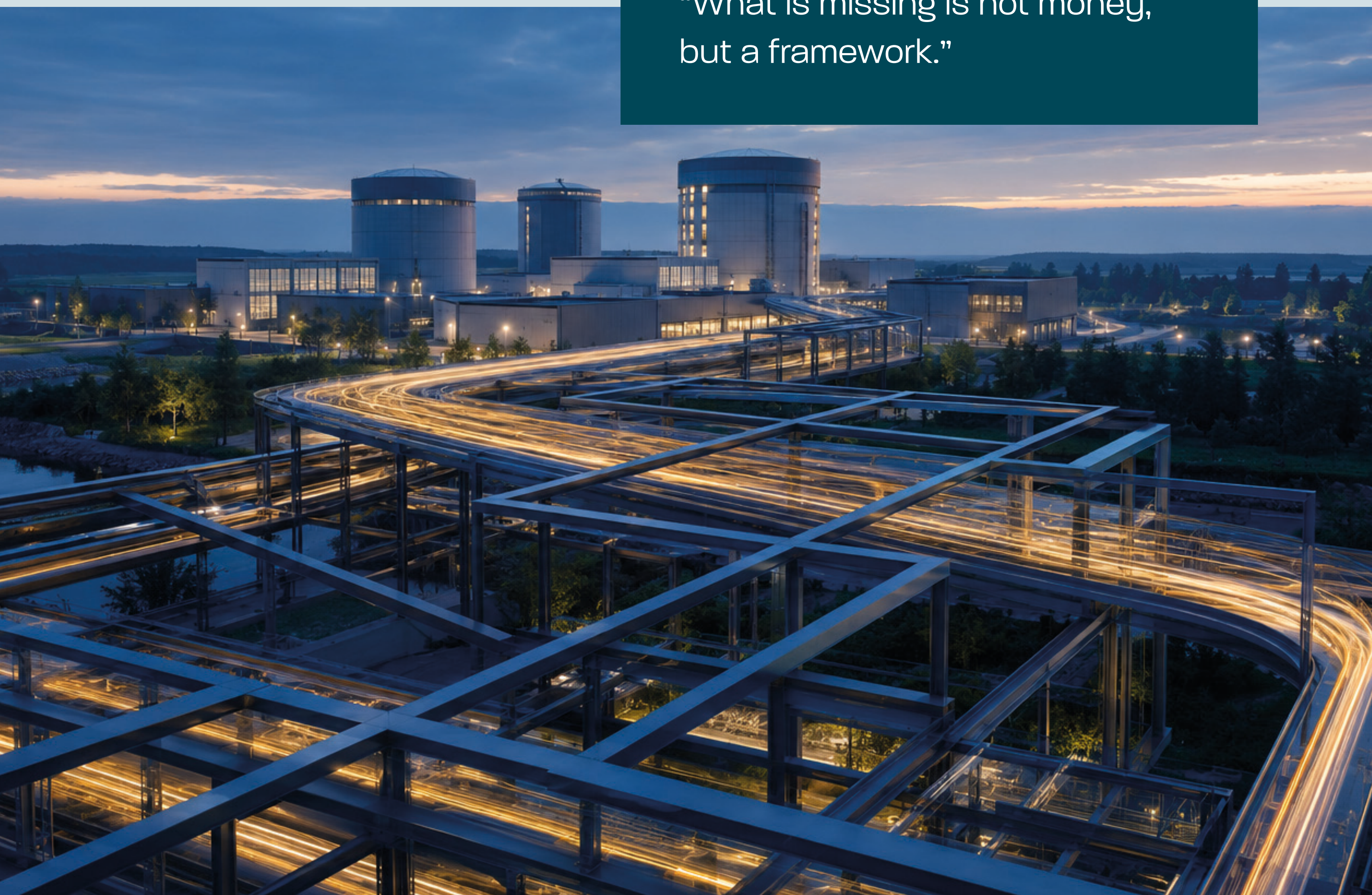
The Department of Energy's Loan Programs Office has provided loan guarantees for advanced nuclear projects, most notably the Vogtle expansion, on the explicit rationale that the financing market for nuclear cannot adequately price first-of-a-kind risk, and that the public interest in establishing a domestic nuclear manufacturing capability justifies limited risk-sharing. Separately, the Inflation Reduction Act introduced a Production Tax Credit for nuclear electricity, structured as a revenue support mechanism that declines as the wholesale electricity price rises, effectively providing a market-compatible price floor without creating windfall profits in high-price environments.[41] None of these instruments represents unconditional public support for nuclear investment.

41 US Department of Energy (2022). *Inflation Reduction Act Guidebook: Clean Energy Provisions*. Washington, DC: DOE.

Each is structured to correct a specific and identifiable market imperfection, including liability pricing, first-of-a-kind risk, and revenue volatility, without eliminating the discipline of market exposure. This is the model that a European SMR financing framework should emulate.

The European equivalent might include: a mandatory commercial insurance layer for SMR operators, set at a level consistent with credible market coverage; a pan-European industry compensation fund, modelled on Price-Anderson's second tier, pooling contributions from all operating nuclear generators across member states; and a clearly capped public backstop, defined in legislation and subject to parliamentary oversight, that activates only in the event of an incident exceeding the industry fund's capacity. This structure would resolve one of the most persistent sources of investor uncertainty (unlimited and uninsurable liability exposure) while keeping the primary financial burden within the industry and away from general taxation.

"What is missing is not money, but a framework."



## 4.6. The State as Rule-Setter, Not Underwriter

The financing of SMRs in Europe is a solvable problem. The capital exists, the technology is advancing, and the demand from both utilities and technology companies is sufficient to make the investment financially viable. What is missing is not money, but a framework within which money can confidently move.

This paper has argued that the framework must be built on three foundations. First, regulatory harmonisation: a mutual recognition regime for SMR type-approval across the EU that eliminates the duplicative costs and delays of national re-licensing, without requiring the politically impractical creation of a European nuclear regulator. Second, market-compatible revenue stabilisation: the facilitation of long-term PPAs, particularly with creditworthy technology-sector offtakers, and the selective, time-limited use of CfDs for first-of-a-kind projects, structured explicitly as transitional instruments. Third, limited and targeted public risk-sharing: a European adaptation of the Price-Anderson model for liability, combined with a clearly capped public backstop, and the strategic use of promotional bank co-investment to bridge the first-mover gap.

What this framework deliberately excludes is equally important. It does not include permanent revenue guarantees, open-ended construction risk absorption by the state, or directed public investment in SMR equity. These instruments are not merely expensive; they are counterproductive, because they replace the discipline of market exposure with the soft budget constraints of public ownership, and the history of state-led nuclear programmes in Europe is not one that inspires confidence.

The state's role in the energy transition is to set the rules, price the externalities, and correct the specific distortions, most of them of its own making, that prevent markets from functioning. In the case of SMRs, those distortions are primarily regulatory and institutional. Removing them is not a subsidy; it is the precondition for everything else. Private capital will do the rest if the framework gives it the confidence to do so.

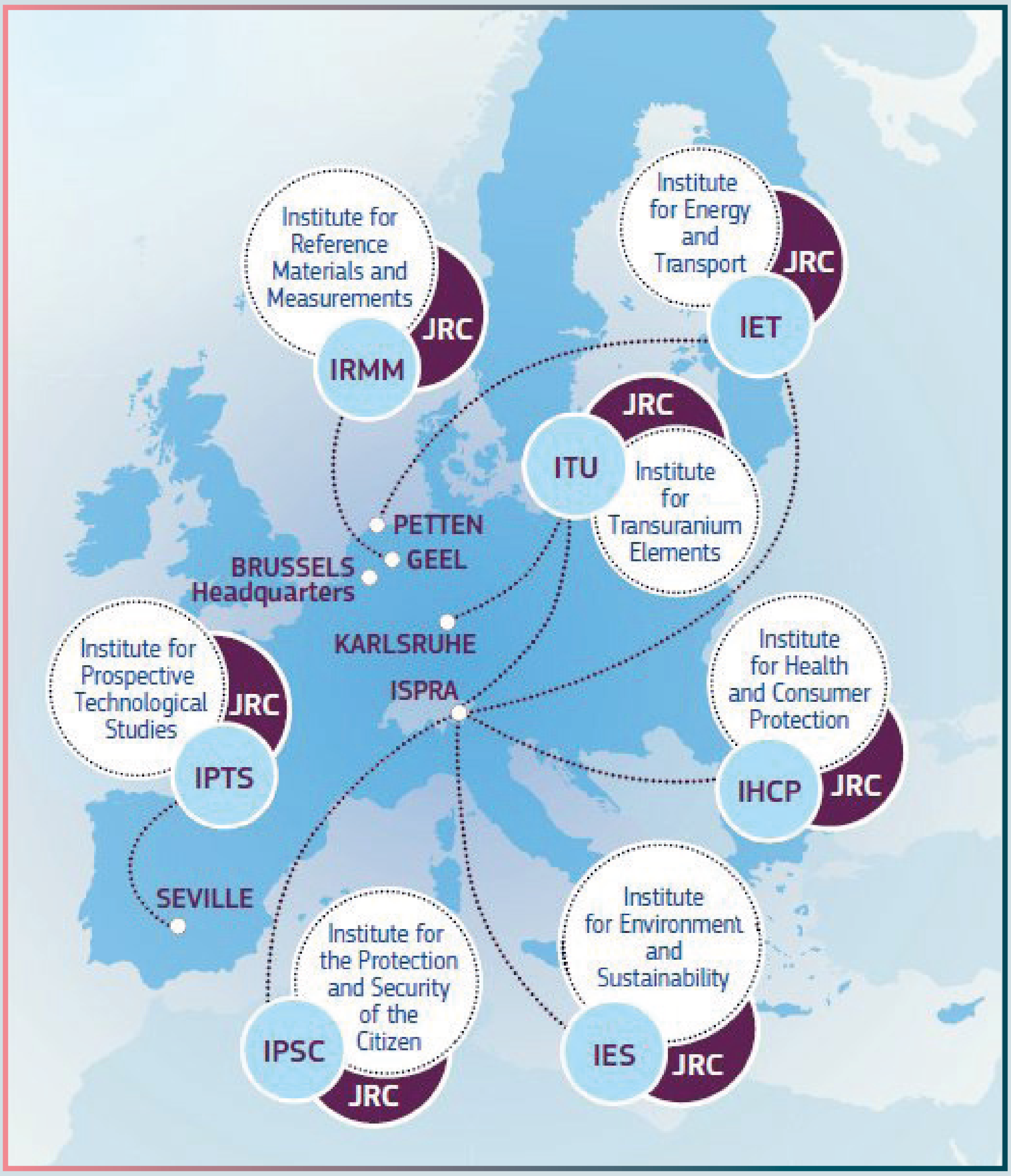
# Chapter 5. Skills, Technology and Workforce Solutions

## 5.1. The "EU SMR Acceleration Hub"

SMRs encompass a wide range of designs, many of which incorporate novel and, in some cases, unprecedented engineering features. This diversity creates a fundamental challenge for regulatory authorities: how to license a technology that has not yet been demonstrated at full scale. This leads to a structural "chicken-and-egg" problem; licensing typically requires operational evidence, yet generating such evidence is difficult without prior regulatory approval to construct and test. One of the key advantages of SMRs is precisely their suitability for full-scale prototyping and testing, in a manner analogous to certification practices in the aerospace sector. However, current regulatory frameworks within the EU do not readily accommodate this approach, limiting the ability to exploit this advantage.

To address this gap, the EU could establish a dedicated **SMR Prototype Testing Park**, or ***EU SMR Acceleration Hub***, leveraging the capabilities and infrastructure of the Joint Research Centre (JRC). The JRC already provides independent, evidence-based scientific support to EU policy and operates large-scale research facilities across multiple Member States, see Figure 8. Building on this foundation, a specialised site or network of sites could be designated for the construction and testing of SMR prototypes.

Figure 8. JRC in EU provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society




Such facilities could be co-located with existing JRC installations or developed as new sites in regions with low population density. The infrastructure would need to include standard research-site provisions: physical security, grid connection or controlled heat rejection systems (e.g., access to a river or cooling basin), and waste management capabilities. Prototype testing would generate radioactive waste streams, requiring on-site interim storage for low-level waste and appropriate handling and transfer pathways for higher-level waste. The physical footprint of individual prototype installations would remain relatively small—approximately one hectare or less—though this would be complemented by a surrounding buffer zone.

This buffer zone would serve as an additional safety margin, with radiological criteria more conservative than those applied to commercial nuclear installations. Importantly, it need not be entirely exclusionary. Portions of the buffer zone outside the immediate facility perimeter could remain accessible for low-occupancy uses such as agriculture, recreational areas, or light industrial activity; land uses that allow for rapid and minimally disruptive evacuation if required. In the event of an incident or credible release scenario, standard protective measures such as shelter-in-place orders could be implemented.

A central design principle of the SMR testing park would be a **user-pays model**. Participating developers ("tenants") would finance the construction and operation of their prototypes, as well as pay fees proportional to their use of shared infrastructure and services. Each developer would retain responsibility for decommissioning its installation and restoring the site to agreed conditions upon completion of testing. This would mean that **the market, and not politicians**, would choose which concepts could apply. It would also mean that, if the Hub is successful, it will minimise the cost to the taxpayer.

> "A central design principle of the SMR testing park would be a user-pays model. Participating developers would finance the construction and operation of their prototypes, as well as pay fees proportional to their use of shared infrastructure and services. Each developer would retain responsibility for decommissioning its installation and restoring the site to agreed conditions upon completion of testing."

Within the proposed SMR Prototype Testing Park, developers would bear full financial responsibility for any harm arising from their activities. To operationalise this principle, participation in the **Hub would require the posting of financial guarantees calibrated to risk**. Specifically, each developer would be required to secure a bond or insurance coverage sufficient to address damages associated with a credible beyond-design-basis accident scenario, as well as a separate financial provision covering decommissioning and site restoration costs.

This mechanism introduces market discipline at an early stage of technology development. If a developer is unable to obtain insurance or post the required bond at an economically viable level, the project would not proceed to testing. In addition, insurers would play an active oversight role. They would appoint qualified technical representatives to monitor testing activities, with the contractual authority to suspend coverage if safety conditions deviate materially from agreed parameters. The withdrawal of coverage would, in turn, trigger an automatic suspension of testing operations until compliance is restored.

To assess risk, insurers would rely on independent technical expertise, drawing on specialised consultants and professional organisations such as the European Nuclear Society or Certification Agencies from Chapter 3. Premiums, coverage limits, and oversight arrangements would reflect this assessment, aligning financial exposure with the underlying risk profile of each prototype.

Public authorities would retain a supervisory role, but one focused on system integrity rather than detailed technical licensing. National regulators, in coordination with the European Union framework, would be responsible for validating the adequacy of financial guarantees, accrediting insurers, and approving the governance arrangements;

including the qualifications and independence of insurer-appointed overseers.

Under this model, candidate SMR designs would face two independent entry conditions before being admitted to the testing park:

1. Demonstration to the regulators that the SMR technology is safe enough to allow them to set the bond at a reasonable level.
2. Demonstration to private insurers that the risk profile is acceptable at a premium level consistent with the developer's economic constraints.

Together, these filters combine regulatory judgment with market-based risk evaluation.

**Figure 9.** Hanford site at the US, in a low pop area, with a heat sink, which could resemble an SMRs Hub

Following completion of the testing phase, the developer would still be subject to the standard licensing process for commercial deployment. However, this process would be informed by empirical operational data rather than relying exclusively on analytical models and simulations. This represents a significant improvement in both regulatory confidence and design validation.

New technologies require prototype reactors, not just so the developers can learn about their design and improve as necessary, but also for the regulators to learn about the technology.

Prototype facilities associated with successful designs could evolve into semi-permanent experimental platforms. These installations would support iterative improvements, long-term performance testing, and validation of design modifications in response to operational feedback. Such incremental innovation is characteristic of mature industrial sectors but remains constrained in nuclear energy due to the high regulatory cost of even minor design changes. A dedicated prototype environment would allow many of these improvements to be tested and demonstrated prior to formal licensing, thereby reducing the burden of subsequent regulatory processes.

This is particularly relevant for SMR concepts offering operational flexibility such as alternative fuel cycles, higher operating temperatures, or advanced materials. Developers could initially deploy conservative configurations and progressively explore enhanced performance regimes following successful demonstration. This staged approach reflects established engineering practice and supports long-term objectives such as improved efficiency and waste minimisation.

For the prototype park to function effectively, an adapted legislative framework would be required. Experimental reactors should not be treated identically to commercial installations; however, this does not imply weaker safety standards. On the contrary, testing activities would be subject to continuous monitoring within a controlled environment, with clearly defined intervention thresholds and rapid-response authority in the event of abnormal conditions.

Finally, the economic model of the Hub within JRC could be strengthened by allowing prototype SMRs to sell the electricity they generate during testing. Given that full-scale tests would produce non-negligible amounts of power, integrating this output into the grid would provide both environmental and economic benefits. For developers, this would create an additional revenue stream, partially offsetting testing costs and facilitating continued innovation within the prototype framework.

## 5.2. Knowledge transfer and workforce replacement

The transition in knowledge transfer and workforce development required to support an expanded SMR sector in Europe could be achieved within a relatively short timeframe—approximately a decade—provided that the institutional measures outlined above are effectively implemented. The European nuclear workforce remains robust, with a strong base of experienced professionals and a steady pipeline of new talent. Notably, even countries without active nuclear power programmes, such as Italy, continue to produce highly qualified nuclear engineers, many of whom contribute to the broader European ecosystem.

The establishment of initiatives such as an EU SMR Acceleration Hub, the development of independent certification agencies, and existing mobility frameworks supported by the EU, including academic exchange programmes, would facilitate the circulation of expertise across Member States. Together, these mechanisms could enable a relatively smooth scaling of human capital aligned with the needs of an emerging SMR market.

However, this outcome is **contingent on timely implementation**. If the proposed institutional and regulatory reforms are delayed for more than a decade, the EU nuclear sector may face a shortage of qualified personnel, particularly as demand increases and experienced workers retire. In this sense, workforce readiness is not an independent variable, but a function of policy execution and market signalling.

# Next Steps Summary Guide

In this document, the opportunity that SMRs represent for Europe have been highlighted. An opportunity for a future of low-carbon, energy security and cheap electricity is open for the next few years but actions should commence as soon as tomorrow if the EU wants to retain nuclear dominance in the upcoming SMR race.

The present document has presented different hurdles that the SMRs will face. Those hurdles are conceptually summarised as follows:

1. Fragmentation of the EU Nuclear Regulation
2. Application of ALARA and precautionary principle
3. EU Financial Instruments associated to nuclear projects
4. Supply Chain Constrain of equipment and workforce

Some of those hurdles could be solved by legislative actions, some by creation, some by elimination. In this report, several solutions have been proposed, some of them directly challenging the status-quo or doing things in the EU. It must be clear however that if the Member States and the EU continue with their inertia, SMRs cheap electricity powered by free-market mechanisms will not be possible. Of course, many of the proposals involve strong involvement from national governments as ultimately, but it may be in all EU interest to collaborate in this endeavour.

The proposals written in this report are conceptually summarised below:

1. Replacement of ALARA with science-based regulation (See Chapter 3.2).
2. Cultivate close collaboration between EU states' regulatory authorities to accept a European Generic Design Application or other countries' licences for SMRs (Chapter 3.3)
3. Use of insurers and certification agencies to reduce regulator's workload and foster free-market dynamics between them. (Chapter 3.4 and 4.5)
4. Foster CfD and PPA agreements between SMRs and energy-consumers (Chapter 4.3)
5. Using the JRC facilities develop and maintain a EU SMR Acceleration Hub (Chapter 5.1)

*What is past is prologue*

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# About ELF

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The Foundation also conducts research on migration, entrepreneurship, fiscal policy, housing, education and institutional quality, with particular attention to migrant entrepreneurship, access to banking services and economic inclusion.

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