In collaboration with
Accenture

A Collaborative Framework for Accelerating Advanced Nuclear and Small Modular Reactor Deployment

WHITE PAPER

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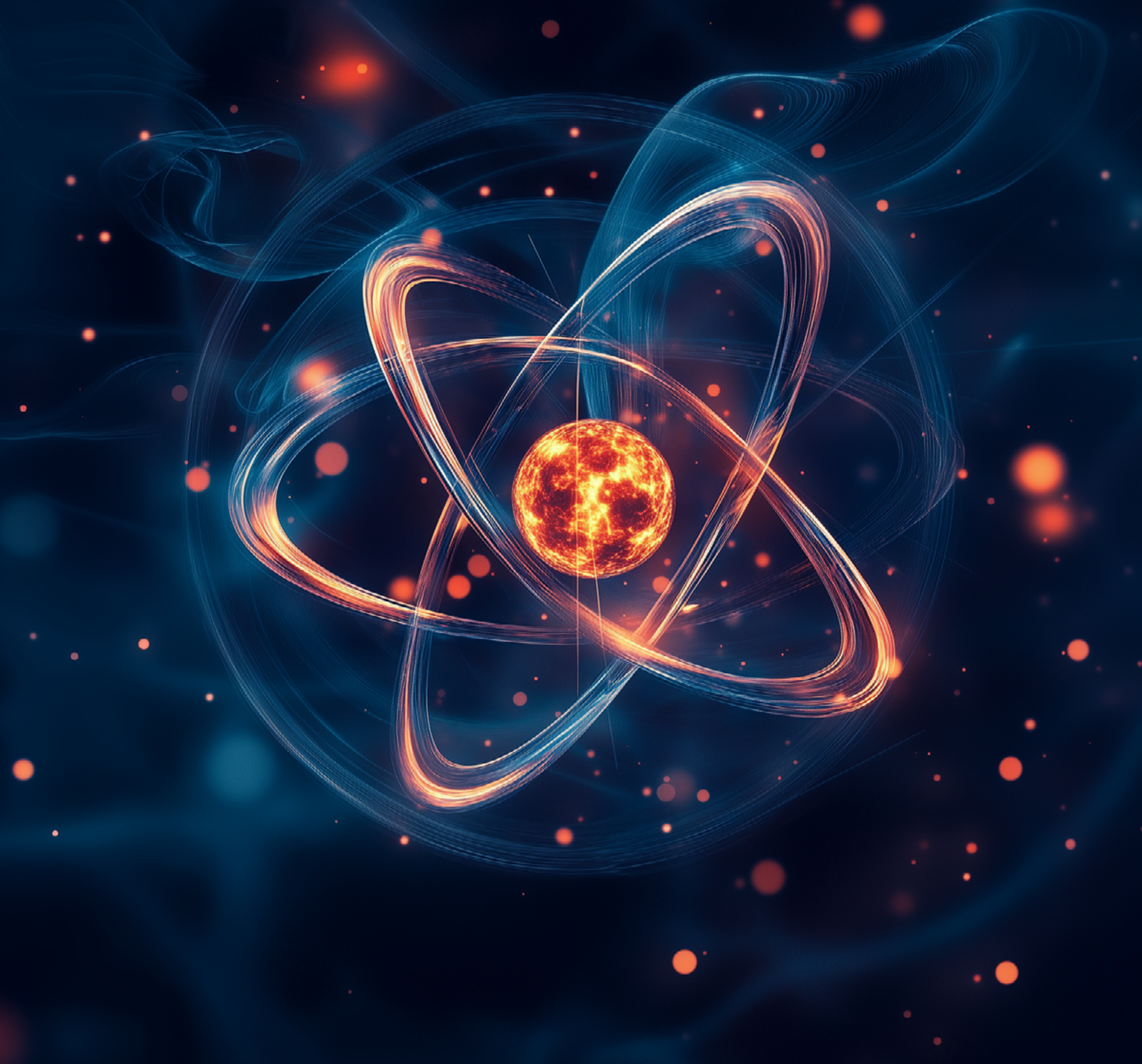

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Contents

Foreword 3

Perspectives from key contributors 4

Executive summary 5

Introduction 7

1 Emergence of the advanced nuclear and SMR market 9

2 Delivering advanced nuclear and SMRs at scale 13

3 Financing advanced nuclear and SMRs 18

Conclusion 20

Contributors 21

Endnotes 23

Foreword

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Demand for carbon-free energy is growing. Increasing adoption of artificial intelligence (AI), electric transport, heat pumps and emerging market growth are driving new industries and countries to consider nuclear energy alongside renewables within their net-zero roadmaps. In response, countries that endorsed the declaration made at COP28 to triple global nuclear power capacity by 2050 were joined by 14 major banks and additional countries in 2024.

To meet net-zero commitments and burgeoning energy demand, nuclear new builds of multiple sizes and technology types will be needed. Small modular reactors (SMRs) and other advanced nuclear technologies represent clean energy solutions that, when built at scale, could deliver cost-effective carbon-free energy. These technologies are well suited to meet many clean power, heat and clean fuel production use cases for heavy industry, data centres and transport. However, the commercial viability of these technologies needs to be improved.

The ecosystem for new nuclear comprises a range of stakeholders including technology developers, financial institutions, utilities, large energy consumers and governments. Reaching commercial viability of advanced nuclear and SMRs is dependent on de-risking and improving the economics of projects through purposeful, coordinated action between these stakeholders – beyond anything seen before. Among other priorities, new approaches are needed to develop supportive government policies and programmes, implement innovative project management techniques, build supply chain readiness and support talent growth.

Stakeholders across the nuclear ecosystem are already taking critical actions, including demand aggregation partnerships between large energy consumers, incorporating nuclear energy into clean investment taxonomies and establishing government programmes to support new-builds. These actions must continue and expand to achieve the system-level change needed. The collaboration framework presented in this report is intended to be a coordination tool for leaders across the nuclear ecosystem to align on actions and strategies to accelerate advanced nuclear and SMR deployment.

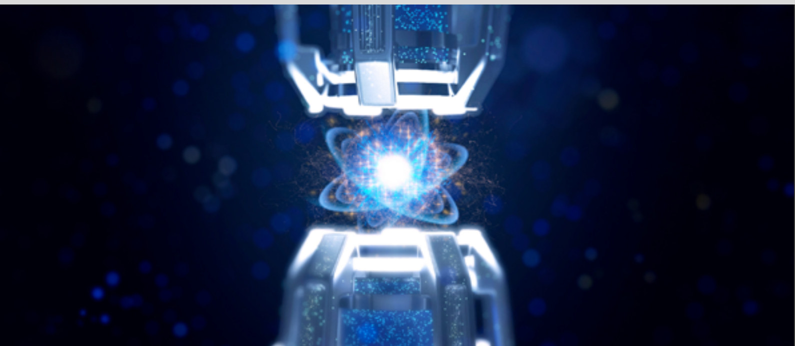
Perspectives from key contributors

Developing countries need reliable power for economic growth, while high-income countries require uninterrupted energy for facilities such as data centres and high-tech manufacturing. Supply chain disruptions and global conflict have renewed interest in nuclear energy for its security, reliability and zero-carbon nature.

At COP28, over 20 countries committed to tripling global nuclear energy capacity by 2050, requiring 25-30 GW to be built annually, starting in 2030. Innovative nuclear companies are working to commercialize new technologies to meet this demand. Scaling nuclear energy globally requires a multi-pronged approach that addresses demand signalling, energy policy, financing and competitive economics.

The world is at a critical juncture — collaborate to scale nuclear energy or miss this pivotal moment.

Jeremy Harrell, Chief Executive Officer, ClearPath



The World Economic Forum's *Framework for Accelerating the Deployment of Advanced Nuclear and SMRs* represents a timely and necessary effort. At nucleareurope, we are proud to have contributed to this collaborative process, aligning our vision of a sustainable, secure and equitable energy future for Europe. Advanced nuclear and SMRs offer dependable, low-carbon energy alongside renewables and can play a critical role in industries and regions where flexibility and scalability are paramount.

This framework's nine priority areas are essential for enabling SMRs in Europe. Innovation through public-private partnerships, streamlining regulatory processes and ensuring a level playing field for all net-zero technologies are crucial to achieving our shared climate and energy goals.

Yves Desbazeille, Director General, nucleareurope

Advanced nuclear energy and SMRs can provide emissions-free, 24/7 reliable electricity and heat worldwide. Industrial users are aiming to decarbonize hundreds of gigawatts of energy applications by 2030. The demand for clean energy is huge and urgent.

Rapid deployment of clean energy requires innovations in design, licensing and delivery approaches, leveraging digital tools. Nuclear energy must shift from construction projects to mass-manufactured products for rapid deployment.

The advanced nuclear and SMR industry success hinges on economic viability and cost-competitive models. Industry collaboration is essential to meet global demand for decarbonization targets and ensure universal access to affordable, reliable and clean energy.

Kirsty Gogan, Founding Director and Co-Chief Executive Officer, Terra Praxis

Executive summary

With increasing demand for clean power, now is the time to deploy and scale-up advanced nuclear and SMRs. This report presents a framework to support and accelerate this process.

The World Economic Forum has partnered with stakeholders across the nuclear ecosystem to develop a *Framework to Accelerate the Deployment of Advanced Nuclear and Small Modular Reactors (SMRs)*. This Framework is a tool that can align stakeholders on key actions and strategies within nine priority areas to accelerate deployment (see Table 1). The Framework has been co-developed with stakeholders from across the nuclear ecosystem including experts from large energy-consuming industries, financiers, reactor vendors, supply chain businesses, utilities, government organizations, non-profits/NGOs and academia.

Implementing this Framework requires collaboration across the nuclear ecosystem to improve the economics of new-builds through cost-competitive deployment models and timely project delivery.

Public-private partnerships are crucial for developing enabling policies, driving modernization of regulations and building a supply chain to deliver advanced nuclear and SMRs at scale.

The Framework and its recommended actions are intended to serve as a tool that a wide range of stakeholders can use to work collectively towards unlocking the systemic changes needed to accelerate the deployment of advanced nuclear and SMRs. The Framework provides a basis for locally led implementation, as priorities will vary across geographies at various stages of nuclear development. It could also apply to other advanced clean energy technologies that require a systemic approach to unlock progress, such as geothermal and long-duration energy storage.

TABLE 1 **Priority areas and actions for accelerating the deployment of advanced nuclear and SMRs**

Priority areas	Recommended actions
Part 1 Emergence of the advanced nuclear and SMR market	
1. Signalling and meeting demand	– Facilitate global and localized demand signals. – Enhance collaboration across the nuclear ecosystem to share risks and costs. – Develop strategies to meet diverse energy needs of power customers and industrial uses.
2. Evolving energy policy	– Include nuclear in clean energy definitions, policies, incentives and energy systems modelling. – Standardize global sustainability criteria. – Create new market routes for private developers and financiers.
3. Modernizing regulation	– Align regulatory bodies to streamline licensing of standard design across countries. – Automate regulatory processes.

Part 2 Delivering advanced nuclear and SMRs at scale

4. Transforming project deployment

- Enhance rapid delivery of cost-competitive projects with:
  - Innovative deployment models.
  - Modular construction.
  - Design for manufacture and assembly (DfMA).

5. Repurposing and clustering infrastructure

- Repurpose existing infrastructure.
- Co-locate reactors with current energy systems.
- Engage communities throughout the project.

6. Maturing advanced energy technology

- Increase maturity and scalability of advanced nuclear and SMR technologies by:
  - Collaborating with regulators and energy off-takers.
  - Standardizing design.

7. Building supply chain readiness

- Prepare nuclear supply chain for large-scale deployment by:
  - Boosting investment.
  - Developing nuclear fuel sources.
  - Standardizing components.

8. Developing talent

- Identify skills gaps.
- Retrain workers from other energy industries.
- Facilitate skills pools.
- Partner between industry and educational institutions.

Part 3 Financing advanced nuclear and SMRs

9. Catalysing investment

- Develop innovative financing mechanisms.
- Leverage public-private partnerships.
- Reach target cost levels to attract mainstream investments.
- Include nuclear in clean investment taxonomies.

Introduction

The global energy system faces growing challenges to meet rising energy demand from electrification, emerging market growth, AI-driven infrastructure and decarbonizing hard-to-abate sectors such as transportation and heavy industry.

Advanced nuclear and small modular reactors (SMRs) are emerging as key technologies to complement renewables and other solutions in the future clean energy mix. These technologies are versatile, require minimal land and have potential for standardized production, enabling them to be rapidly scaled-up and meet industrial demands for clean, reliable, abundant, 24/7 power, heat and synthetic fuels.

However, uncertainties remain about who will lead deployment and scaling-up, who the core customers will be and how to de-risk and mobilize investment. While utility companies traditionally lead grid-scale nuclear delivery, new entrants like large energy consumers are now exploring their roles in new nuclear builds.

The World Economic Forum has partnered with stakeholders across the nuclear ecosystem to develop a *Framework to Accelerate the Deployment of Advanced Nuclear and Small Modular Reactors (SMRs)*. This Framework aims to align stakeholders on key actions and strategies within nine priority areas to accelerate their deployment of advanced nuclear and SMRs (see Table 1 above and Figure 1).

This report examines each of the Framework's priority areas and recommended actions under the following headings:

– Part 1: Emergence of the advanced nuclear and SMR market

– Part 2: Delivering advanced nuclear and SMRs at scale

– Part 3: Financing advanced nuclear and SMRs

BOX 1

Advanced nuclear and small modular reactors (SMRs)

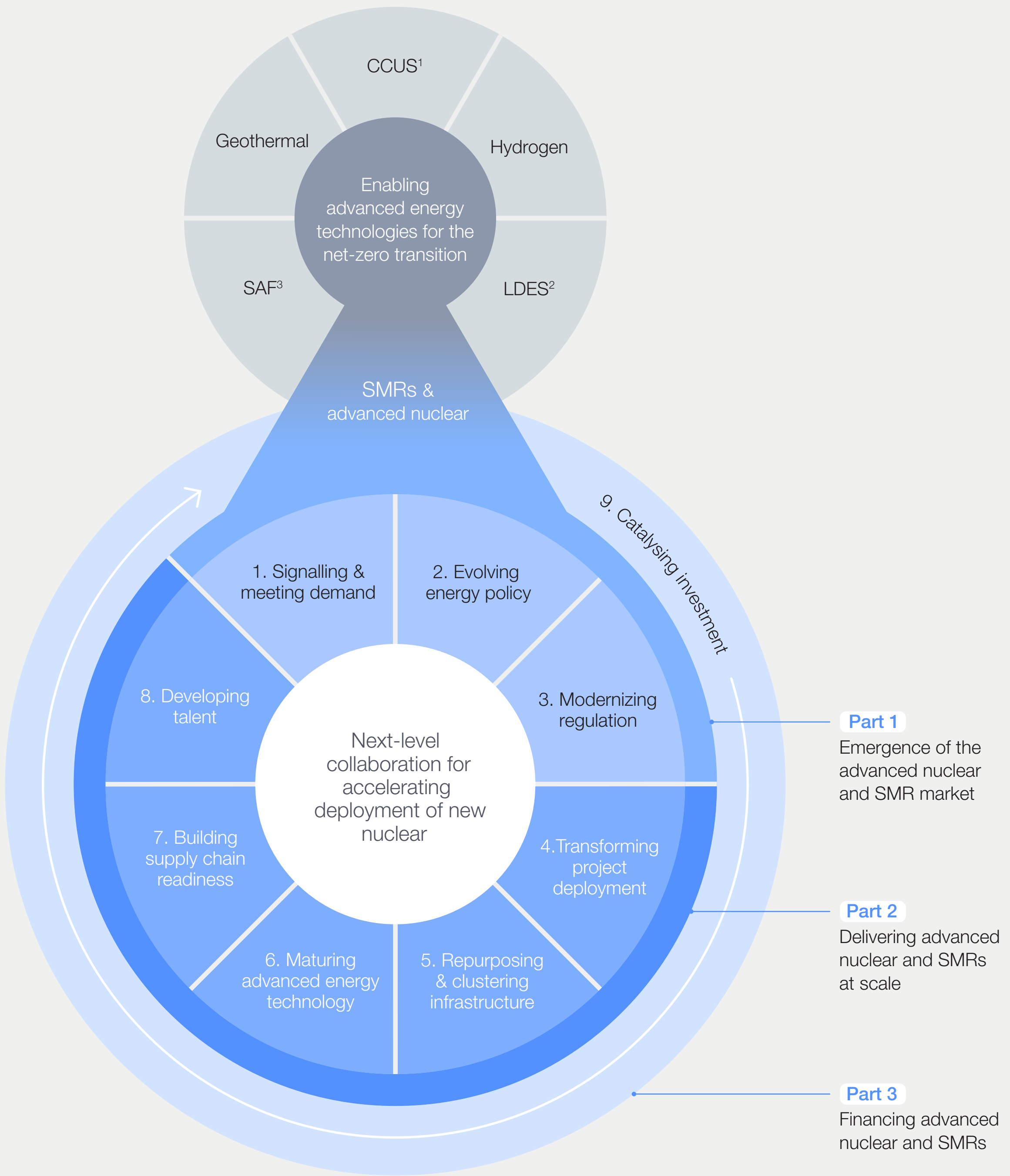
Like conventional nuclear reactors, advanced nuclear reactors and SMRs generate electricity and heat through nuclear fission. However, SMRs have a smaller footprint and generating capacity (typically below 500 MW). They are designed to be built with standard components, replicable manufacturing processes and modular assembly.

On this basis, SMRs are a viable option for powering remote areas and for industrial and transport applications. SMRs span a multitude of reactor designs, including water-cooled and non-water-cooled reactor technologies.

Advanced nuclear designs also incorporate innovations such as new safety features, improved reactor efficiency, new fuel types and improved integration with renewables and other power sources.

Sources: World Nuclear Association (WNA), ClearPath.[1]

FIGURE 1 | **Framework for Accelerating Advanced Nuclear and Small Modular Reactor (SMR) Deployment**



Note: 1. CCUS: Carbon capture, utilization and storage 2. LDES: Long-duration energy storage 3. SAF: Sustainable aviation fuels

1

Emergence of the advanced nuclear and SMR market

Priority area 1

Signalling and meeting demand

Countries with nuclear operations and those planning new developments are signalling demand for SMRs to support energy security, economic development and decarbonization.[2] New players, namely large energy consumers, are also exploring nuclear, as shown by the demand aggregation partnership between Google, Nucor and Microsoft.[3]

Ecosystem collaboration must facilitate stronger demand signals to stimulate confidence among public and private investors. Examples include:

- Reactor vendors, developers, owner/operators, large energy consumers and utilities aggregating demand to reduce early-stage and single-party financial risk for project development.
- Large energy consumers with differing needs (e.g. electricity, heat, hydrogen and zero-carbon fuels) partnering to create offtake certainty and to engage financiers early, enabling access to cost-efficient capital.
- Governments and large energy consumers committing to nuclear as part of their clean energy strategies to reduce uncertainty of demand for utilities, developers and financiers.

CASE STUDY 1

Establishing Great British Nuclear (GBN)

Even with projects like Hinkley Point C and Sizewell C, nuclear generation capacity growth remains insufficient to meet the UK's long-term net-zero and energy security goals. To address this, the Department of Energy Security and Net Zero (DESNZ) established Great British Nuclear (GBN), an expert organization focused on delivering His Majesty's Government (HMG) nuclear programme, including designing, constructing, commissioning and operating nuclear projects.

GBN will provide a range of support, including developer capability, site access and funding to mature technologies, to reduce risk and accelerate deployment. Initially focusing on SMRs, GBN is running a competitive process to select the best technology designs. Four technology providers have been shortlisted.

Working with industry, GBN aims to accelerate technology development, mobilize supply chains and reduce early-stage risks to achieve the UK's energy independence and net-zero ambitions.

Source: Great British Nuclear

Priority area 2

Evolving energy policy

Existing policies are expected to increase global nuclear energy capacity by around 48% between 2022 and 2050.[4] This falls short of national pledges made at COP28 and industry-led demand for clean heat and power to support data centres and repower industry and coal. Additionally, current nuclear energy policies are not necessarily geared towards new technologies.[5]

Deployment depends on policies that address specific challenges, such as improving supply-chain stability and creating vehicles for strategic partnerships across ecosystem stakeholders. Recommended actions for governments are proposed in Table 2.

Direct government investment in nuclear reactor technologies, construction and the supply chain are helping drive deployment in some countries, such as Poland and the US.

TABLE 2 **Evolving energy policy recommended actions and examples**

Recommended actions	Examples
Ensure that clean energy and nuclear legislation is informed by expertise from the nuclear industry.	The Finnish government worked with the nuclear ecosystem to create leading nuclear waste management regulations and solutions. Posiva Oy, founded by two nuclear plant operators, in collaboration with the Finnish government and the local community, established the world's first final repository for spent nuclear fuel, using a method developed by Swedish company SKB.[6]
Support inclusion of nuclear energy in taxonomies, energy systems modelling and standards for "clean" and "green" energy, creating incentives aligned with other sustainable energy technologies.	The European Union's Sustainable Finance Taxonomy recognizes nuclear energy as a sustainable replacement for fossil fuels. Canada includes nuclear expenditures as eligible under its Green Bond Framework as of November 2023.
Introduce policy and financing that support the growth of domestic nuclear supply chains.	The Sapporo 5 partnership between the UK, US, Canada, France and Japan has committed to mobilize $4.2 billion to expand enrichment and conversion services. The US established the high-assay low-enriched uranium (HALEU) Availability Program and put $2.7 billion towards producers of low-enriched uranium.[7]
Improve coordination and momentum through government, industry and NGO-backed commitments.	At COP28, the World Nuclear Association and the Emirates Nuclear Energy Corporation (ENEC) launched the Net Zero Nuclear campaign, with support of the Atoms4NetZero initiative and the UK government. This led to over 20 national commitments to triple nuclear energy capacity by 2050.[8] The International Atomic Energy Agency's (IAEA) Nuclear Energy Summit 2024 built on this,[9] with over 30 national leaders committing to "unlock the potential of nuclear energy".

BOX 2 Countries must collaborate to address barriers to cooperation

Recognition that nuclear energy plays a key role in reducing emissions and providing reliability in the US has led to supportive policy and funding. The US Advanced Reactor Demonstration Program (ARDP) awarded federal support of over $2 billion to TerraPower and over $1.2 billion to X-Energy, matched dollar-for-dollar by private investments, to construct commercial demonstration reactors.

Not every country can provide this level of financial support, but there are additional areas where countries can collaborate. Recently, Poland and 18 other European countries applied to establish a working group to support commercialization of GE Hitachi's BWRX-300 reactor.

Source: ClearPath

BOX 3 European Union (EU) call to action

In its 2024 manifesto, nucleareurope called on EU policy-makers to take several actions:

– Develop long-term policies to facilitate lifetime extension of existing fleets and support deployment of new nuclear, including large-scale reactors and SMRs.

– Ensure taxation policies do not discriminate against low-carbon technologies, providing a level playing field for all net-zero solutions.

– Broaden access to EU funds beyond the European Atomic Energy Community (Euratom) to scale-up and finance the mass deployment of nuclear technologies.

– Support nuclear research in the EU, such as doubling the Euratom research and training programme budget. Increase synergies with other EU R&D programmes.

– Enable access to private and public financing for all viable energy transition solutions.

– Ensure that European financial institutions finance nuclear projects for long-term operation of existing reactors, new-builds and fuel cycle facilities.

Source: nucleareurope

Priority area 3

Modernizing regulation

Currently, nuclear licensing and regulation are country-specific, but multinational collaboration could improve efficiency for standardized designs.

Over 80 SMR design concepts are at various stages of development.[10] While only some will achieve commercialization, licensing and regulatory processes must adapt to support multiple reactor vendors in achieving design certification. Currently, nuclear licensing and regulation are country-specific, but multinational collaboration could improve efficiency for standardized designs.

According to the IAEA, around 30 countries are considering nuclear power for the first time and must develop the technical capacity to safely build and operate plants. Expanding regulatory talent through pooling skills, training and employee loan/exchange programmes can provide embarking countries with the resources and best practices needed to progress nuclear programmes.

Additional actions to modernize and streamline SMR regulatory processes include:

- Licensing modular reactor components, such as fuel pumps, to reduce time to license designs built with standard components.
- National regulatory bodies aligning on process commonalities and limiting engagement points and requirements faced by organizations deploying the same technology in multiple countries.
- Collaborating between the nuclear ecosystem and regulatory bodies to streamline licensing and deployment. Analysis of Gen III+ light water reactors indicates that these improvements can reduce costs by 30%.[11]
- Collaborating with local and international experts to transfer knowledge. UAE adopted the IAEA's Milestone Approach, allowing them to quickly establish an independent regulatory body and submit an application for siting and construction licences in just over a year.[12]

CASE STUDY 2

Nuclear Harmonization and Standardization Initiative (NHSI)

The Nuclear Harmonization and Standardization Initiative (NHSI) was launched to globally deploy safe advanced nuclear reactors via industry and regulatory tracks. The industry track prepares stakeholders for large-scale SMR deployment, while the regulatory track develops a global framework for SMR design reviews. Both tracks aim to implement processes, capture lessons learned and improve support for embarking countries.

Source: International Atomic Energy Agency (IAEA)

CASE STUDY 3

Innovative solutions are helping reduce siting and licensing times

Artificial intelligence could reduce human hours for nuclear plant approval by up to 90%. Terra Praxis and Microsoft are collaborating to create tools that automate the evaluation, design and regulatory approval processes for converting coal plants into clean energy investment opportunities.

Terra Praxis and Microsoft also launched the first version of an open access EVALUATE application to enable stakeholders to quickly assess the site-specific business case for repowering coal plants. Features include estimated project costs and savings, reduced carbon emissions and comparisons to alternative technologies.

Source: Terra Praxis

2

Delivering advanced nuclear and SMRs at scale

Priority area 4

Transforming project deployment

> New project delivery approaches can support a competitive levelized cost of energy, especially through modularization to enable increased factory-led production.

The US Energy Information Administration (EIA) projects global electricity demand could increase by three-quarters by 2050 compared to 2023 levels.[13] Meanwhile, planned nuclear plant additions between 2020-2050 fall 681 GW short of the target set by the Intergovernmental Panel on Climate Change (IPCC) of 1,160GW installed capacity by 2050.[14] SMRs could help address this gap, with first-of-a-kind (FOAK) units anticipated this decade and rapid deployment in the 2030s.[15] To meet demand, the industry must achieve economies of scale and reduce the levelized cost of energy (LCOE) across diverse energy markets. New project delivery approaches can support a competitive LCOE, especially through modularization to enable increased factory-led production. As plant designs standardize, project delivery models can prioritize replicable manufacturing, assembly and construction.

Lessons from past projects and other industries demonstrate that steep, near-term cost reduction is achievable by shifting from traditional construction projects built onsite to high-productivity manufacturing environments like shipyards or factories. Moving to highly integrated manufacturing, assembly and installation on one site can enable repeatable processes, with quality assurance designed into every step. For example, the aerospace industry achieved transformative cost reductions and safety improvements through standardization of design and suppliers.

Collaborating to share and institutionalize knowledge can reduce future project schedules. For example, Plant Vogtle 3 and 4, the newest nuclear builds in the US, found that digitizing construction processes and maintaining configuration control improved construction efficiency between units. Configuration control of as-built projects and reconciliation to the standard design and licensing will remain priorities for new-builds as the industry grows.

BOX 4

Plant delivery integration

The complexity of nuclear energy projects can cause fragmentation between the owner/operator, EPCs (engineering, procurement and construction firms), supply chain companies and off-takers. The unequal distribution of risk, management and accountability leads to inefficiencies. The creation of independent nuclear development organizations (INDOs) could integrate and accelerate project delivery within a market, region or across regions. Such organizations, while commercially focused, would have a public purpose and be reactor-, vendor- and geopolitically neutral to focus on building standardized products quickly and efficiently.

Source: Clean Air Task Force (CATF)

Examples of innovative approaches to project delivery include:

- Applying digital tools for accurate, performance-based project budget and timeline estimates and project management (e.g. supply chain forecasts).
- Maintaining a data model and standardized design documentation throughout construction.
- Digitizing plant design and construction processes to improve construction management.
- Adopting modern methods of construction (e.g. DfMA) and building on innovations from aviation, freight and automation.
- Utilizing open architecture by collaborating among stakeholders to agree on a common but customizable modular architecture with standardized interfaces to reduce project costs and timelines.[16]
- Evaluating contracting models with EPCs and developers to share risks and incentivize efficient deployment. Examples include the integrated project delivery (IPD) approach adopted by Ontario Power Generation for its Darlington SMR project; and the prime contract structure used for the Barakah nuclear power plant, United Arab Emirates' first nuclear power station, which achieved a 40% schedule improvement from the first to fourth unit.

Priority area 5 Repurposing and clustering infrastructure

Repurposing existing infrastructure and industrial sites for new nuclear projects can improve project economics through capitalizing on existing grid connections, land availability and – in some cases – equipment to provide low-carbon heat or power. It can also help with local economic development and job creation for workers, who would otherwise be negatively impacted by the energy transition, as well as minimize the environmental impact of facilities being developed on new sites. To accelerate efficient deployment, siting strategies could include the following:

- Repowering retired or soon-to-be-retired coal and fossil fuel plants with SMRs and co-locating energy-intensive infrastructure. Nuclear can match coal's capacity to generate steam at the high temperatures needed in industry, through replacing coal boilers while making use of existing steam turbines, generators, grid connections and water-cooling supply.[17]
- Siting SMRs on land with grid connections repurposed from nuclear sites that are decommissioned or soon-to-be decommissioned.
- Incorporating SMRs into industrial clusters and interconnected infrastructure with appropriate retrofitting and safety measures.
- Engaging with local communities in the early stages of development to address equitable outcomes, including creating jobs and assessing the impact on natural ecosystems.
- Reducing repetition in licensing and reviews of sites with multiple reactors to enable efficient scaling-up.
- Elevating local communities in project planning to improve the economic case and outcomes, including job creation and economic development.

BOX 5

New reactor designs open new opportunities in plant siting

Due to considerations around the need to improve safety and reduce the size of reactors, new reactor designs offer greater flexibility and opportunities in plant siting – such as reduced land area, densely populated areas, brownfield locations, emergency planning zones and locations with scarce water resources.

Source: Electric Power Research Institute (EPRI)

Priority area 6

Maturing advanced energy technology

Technology readiness includes demonstrating a mature plant design, design licences for reactors, supply chain readiness and nuclear fuel availability. Reactor vendors can advance technology readiness by collaborating with:

- Owners/operators and developers to optimize equipment and manufacturing processes.
- Other reactor vendors to share and standardize best practices, while protecting intellectual property.
- Regulators and customers to ensure whole-plant design suits intended use cases and delivery methods. Consider innovative business models including build-own-operate (BOO), independent power/energy/water producer, energy-as-a-service (EaaS) and assets-based financing.
- Research laboratories, academia, non-profits and technology companies to lead innovation in design, manufacturing and construction methods, fuel innovation, waste management/recycling and environmental protection.

The first projects built will pave the way for the standardization of components and production methods. For example, China Huaneng Group's HTR-PM plant features more than 2,200 sets of first-of-a-kind equipment. The supporting fuel element production line has the largest production capacity in the world.[18]

> **To scale SMRs and catalyse investment, governments and regulators must work with reactor developers to reduce technology and project development risk earlier in the development cycle and do so reliably and predictably.**
>
> Rachel Slaybaugh, Partner, DCVC

Priority area 7

Building supply chain readiness

Between the mid-1990s and early 2010s, the nuclear energy industry experienced limited growth leading to a decrease in nuclear-grade suppliers and expertise.[19] Demonstrating SMR demand certainty through off-take agreements, government policy and financial support can prompt the supply chain to rapidly scale-up. Examples of recommended actions that can increase supply chain security and readiness are presented in Table 3.

TABLE 3 **Building supply chain readiness – recommended actions and examples**

Recommended actions	Examples
Governments and financial institutions to support nuclear deployment, commercialization and scaling-up by investing in the domestic supply chain.	Through investments by the government in China National Nuclear Corporation, China aims to produce one-third of its uranium domestically.[20]
Project developers to procure contracts from a strategic mix of local, national and global suppliers.	Electricité de France (EDF) commissioned the Hinkley Supply Chain Team in the United Kingdom to source local and regional suppliers through an application, capability-matching and engagement process that has attracted over 4,000 businesses to the project.[21]
Reactor vendors to collaborate with academia, training centres and skills pools to train the supply chain workforce.	Rolls-Royce SMR has established a partnership with Sheffield University to launch a new manufacturing and testing facility in the United Kingdom.
New methodologies to improve accessibility and quality-assurance of nuclear components and materials.	The European Union and the US Nuclear Regulatory Commission (NRC) have outlined methodologies and quality assurance for “commercial grade dedication” to verify and establish confidence in items manufactured under non-nuclear-specific quality control standards to be used in nuclear applications.

Geopolitical conflicts highlight the need for resilient domestic supply chains to enhance energy security. Kazatomprom, the world’s largest uranium producer, has warned of supply obstacles due to Russia-Ukraine war sanctions. Addressing fuel supply challenges requires investment in mining, enrichment, manufacturing and fuel efficiency for future reactors. Advancements in high-assay low-enriched uranium (HALEU) and mixed oxide (MOX) fuel are crucial for SMRs and advanced nuclear but are currently underproduced.[22,23]

Government investment is critical to scale-up the nuclear supply chain to support robust new-build programmes, but early investments carry risk. Localized demand signals with off-take agreements can de-risk investment by clarifying timelines to achieve critical mass.

Priority area 8 Developing talent

Each gigawatt of nuclear power generates approximately

50k

direct labour years of employment over its lifetime.

Each gigawatt of nuclear power generates approximately 50,000 direct labour years of employment over its lifetime,[24] creating long-term, high-quality jobs and sustainable economic development. For example, the Darlington SMR project is estimated to contribute CAD 15.3 billion to Canada's GDP over 65 years and support 2,000 jobs annually for 65 years.[25] With similar projects on the horizon, the nuclear industry requires a comprehensive talent strategy, addressing technical and non-technical skills.

Public-private partnerships can bridge skills gaps by funding curricula co-designed by industry and academia. For example, Emirates Nuclear Energy Corporation (ENEC) partnered with Khalifa University and Emirates Nuclear Technology Centre on a school programme to develop technical, innovation and entrepreneurship skills. The programme collaborated with international nuclear innovation partners, included visits to the Barakah nuclear energy plant, and focused on research and development for next generation nuclear.[26] Additionally, as fossil fuel assets are replaced with low-carbon alternatives, re-training energy industry workers can bolster the nuclear skills pool.[27]

3 Financing advanced nuclear and SMRs

Priority area 9 Catalysing investment

Catalysing investment is necessary given the significant capital required to finance advanced nuclear and SMR projects. As the nuclear ecosystem collaborates to drive actions and strategies in priority areas 1-8, continuous alignment with financial institutions is crucial. This alignment will help to ensure projects are investable and to drive the economies of scale needed to reduce the initial capital costs and construction risks associated with FOAK projects.

“ **For financiers assessing SMR projects, validation and input is crucial from: (1) industrial players, bringing experience and insights; (2) research centres (for early-stage investors), providing cutting-edge knowledge; (3) policy-makers, influencing and enforcing regulations; and (4) innovators, driving new ideas and approaches.**

Mathieu de Lophem, Founding Partner, Nuketech

BOX 6

Building multiple reactors can distribute first-of-a-kind capital costs

SMR developers aim to achieve economies of scale to reduce initial capital costs and mitigate construction risks while offering potential for diversified revenue streams. Although no current SMR project provides realistic cost estimates associated with serial production, collaborative efforts among the nuclear industry, policy-makers and regulators are essential to pave the way for financing and adopting SMRs.

Building multiple reactors within a single country or through regional collaboration can distribute first-of-a-kind costs across projects, eventually achieving economies of scale. Inter-country agreements can further share initial costs and reduce financial risks, facilitating market entry of both traditional large reactors and SMRs.

Source: International Atomic Energy Agency (IAEA)[28]

Green bonds and loans, coupled with guarantees, are some of the financing mechanisms that can serve as tools for facilitating risk mitigation and broader investor participation.[29] Lessons from past nuclear builds emphasize the value of government-backed programmes that provide guardrails or insurance mechanisms.[30] Export guarantees, provided by export credit agencies, can help increase banking liquidity to finance projects. Such government-backed organizations include Italy’s SACE, Spain’s Cesce, Korea’s Eximbank and Etihad Export Credit Insurance. Grants and tax incentives similar to those that have advanced renewable technology and deployment can also support nuclear.

Governments and multilateral organizations can reduce risk for investors by including nuclear in clean energy and decarbonization taxonomies, which then impacts investment decisions and frameworks such as environmental, social and governance (ESG). Nuclear energy is also being integrated into green financing frameworks by utilities across the globe.

Along with private sector stakeholders, who will increasingly need to contribute to financing, international finance institutions (IFIs), including multilateral and bilateral development banks, can provide support by including nuclear in their lending.[31]

> **Harmonizing global green taxonomy criteria for positive impact investments would enhance investor certainty and boost confidence.**
>
> Gerard Vinals Foguet, Executive Director, Loan Capital Markets and Sustainable Finance, First Abu Dhabi Bank (FAB)

CASE STUDY 4

Creating a new multilateral financial institution for nuclear

The International Bank for Nuclear Infrastructure (IBNI) is a conceptual new multilateral IFI aimed at supporting embarking countries and nuclear-exporting countries in accelerating the development and rapid expansion of nuclear energy capacities through financing and other support. IBNI seeks to enable nuclear technologies to rapidly de-risk, scale-up and improve cost curves.

IBNI would offer "stapled financing"[32] and other support tools that qualified suppliers and developers could offer their customers. This would promote risk mitigation, cost reduction and certainty, and rapid growth in global firm order flows. This extends to infrastructure needed to rapidly scale-up nuclear energy, including skills pools, global supply chains, nuclear fuel cycle facilities and repositories. Examples of proposed IBNI financing and support tools include:

- Emerging technologies supplemental grant and concessionary financing.
- Committed equity financing of projects and companies through supply chains.
- Committed senior and/or subordinate debt financing.
- Hedging contracts: interest rates, inflation, currency risks.
- Completion risk insurance and committed contingent debt and/or equity financing (in case of delays and overruns).
- Commercial guarantees and sovereign risk guarantees

Source: International Bank for Nuclear Infrastructure (IBNI)

Conclusion

In the global effort to transition to clean energy, countries can apply this Framework to deploy advanced nuclear and SMRs in ways tailored to local contexts and pathways.

Advanced nuclear and SMRs are crucial technologies to contribute to a secure, sustainable and equitable energy transition. This Framework, developed with nuclear ecosystem stakeholders, serves as a multistakeholder tool to drive the systemic change needed for new nuclear development. While countries with established nuclear programmes and those embarking on nuclear development will have different approaches, the Framework can be tailored to specific contexts and implementation pathways.

As the demand for clean energy grows, government and business can collaborate to implement a range of actions and strategies to accelerate new technologies through creating the right policy environment, modernizing regulations, strengthening the supply chain and building the talent pool. New industry collaborations are also important, including sharing knowledge from past projects.

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Endnotes

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32. "Stapled financing" is a financing package arranged by a seller for potential purchasers as part of an auction process. It is organized by the seller and their financial advisors, and it comprises the principal, fees and loan covenants. In this case, stapled financing is organized by the investment bank and made available to private organizations to bid for.

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