Strategic Energy Technology Plan

Implementation Working Group on Nuclear

Thematic Vision on Nuclear

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Executive Summary

Nuclear energy remains a cornerstone of the European Union's pathway toward climate neutrality, energy security, and industrial competitiveness. Within this context, the Implementation Working Group (IWG) on Nuclear, operating under the Strategic Energy Technology Plan (SET Plan)[1], plays a primary role in coordinating research, innovation, education, training and policy alignment across the full nuclear lifecycle. This Thematic Vision provides a forward-looking strategic framework to guide the IWG's actions over the coming decades, responding to evolving political, technological, economic, and societal challenges.

The Vision articulates how nuclear technologies—fission and fusion—can continue to deliver safe, reliable, low-carbon energy while reinforcing Europe's strategic autonomy and technological leadership. It covers existing reactor fleets under long-term operation, new builds, Small Modular Reactors (SMRs), advanced modular and Generation IV systems (AMRs), spent fuel and radioactive waste management, decommissioning, medical and industrial applications, research infrastructures, skills, digitalisation, and societal engagement. The document aligns closely with recent EU initiatives, including the revised SET Plan governance, the Net-Zero Industry Act[2], the Nuclear Illustrative Programme (PINC)[3], the SAMIRA Action Plan[4], the European Industrial Alliance on SMRs[5], the European commission (EC) communication 'Strategy for the development and deployment of SMRs in Europe'[6], the proposal for an industrial accelerator act[7] and the upcoming European Union (EU) Fusion Strategy[8].

In the short term (to 2030), the Vision prioritises long-term operation of the existing nuclear fleet as well as new-build of large NPPs, applying the highest achievable safety standards supported by consolidated scientific evidence for ageing management, strengthened severe accident management capabilities, and consistency in regulation application in EU Member States (MS). It aims to enable first-of-a-kind deployment steps for SMRs, to advance demonstrators for AMR's technologies, to consolidate geological disposal and decommissioning expertise, to strengthen radioactive waste management strategies, to modernise ageing R&D infrastructures, to secure the supply of medical radioisotopes and their precursors, to ensure protection of workers, people and the environment and to develop a robust European nuclear skills framework across all disciplines. Cross-cutting priorities- digitalisation, circularity, cybersecurity, radiation protection and societal acceptance- are integrated across all IWG activities.

In the medium term (to 2040), the vision envisions an integrated and technologically mature European nuclear system, characterised by at least a "partially" harmonised safety frameworks, interoperable data and monitoring platforms, industrialised decommissioning capabilities, and advanced reactor

[1] SETIS - SET Plan Information System - SETIS - SET Plan information system

[2] Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724Text with EEA relevance.

[3] Communication on the Nuclear Illustrative Programme under Article 40 of the Euratom Treaty - European Commission

[4] SAMIRA Action Plan - European Commission

[5] European Industrial Alliance on Small Modular Reactors - Internal Market, Industry, Entrepreneurship and SMEs

[6] IMMC.COM%282026%29117%20final.ENG.xhtml.2_EN_ACT_part1_v9.docx

[7] Industrial Accelerator Act - Internal Market, Industry, Entrepreneurship and SMEs

[8] EU Commission Includes Fusion As A Priority In Its 2026 Work Programme - Fusion Industry Association

technologies ready for early commercial deployment. Enhanced fuel-cycle sustainability, improved resource efficiency, and strengthened cross-border cooperation will underpin Europe's strategic autonomy and resilience. Regarding fusion research and innovation, it is expected to have delivered robust EU scientific and engineering capabilities, governance and infrastructure and evidence, through devices such as ITER and European demonstration initiatives, establishing a credible technical foundation for the longer-term commercial viability of fusion energy. Europe should also achieve a mature and a highly integrated nuclear education ecosystem that supports the commercial deployment of advanced nuclear technologies

In the long term (to 2050), the Vision outlines a fully mature EU nuclear system combining the highest safety standards with climate neutrality and global leadership. Advanced fission and fusion energy technologies are expected to contribute at scale to electricity generation, industrial and district heating, hydrogen and molecules production, and emerging applications, supported by advanced fuel-cycle capabilities (e.g. new processing, enrichment, metallization, manufacturing, continuous multi-recycling, and advanced reprocessing capabilities) and a coherent set of deep-geological repositories. By articulating clear ambitions and milestones, this Thematic Vision provides a coherent roadmap to align national and European efforts, support evidence-based policymaking, and ascertain that nuclear energy continues to serve European citizens, industry, and society safely and sustainably. Alongside, Europe should possess a globally recognized nuclear education and skills ecosystem that supports a mature, innovative and sustainable nuclear sector.

The objectives of this vision document are clearly aligned with the time horizons of the SET Plan pillars as illustrated in the table below:

Objectives	**SET Plan Pillar**	**By 2030 (Short Term)**	**By 2040 (Medium Term)**	**By 2050 (Long Term)**
Safety & Regulatory convergence	Safety / Governance	Consolidate LTO evidence and ageing management; initial convergence on licensing practices in the EU	Shared Safety Case methodologies for at least 5 EU countries Clarity on the EU regulatory framework on fusion energy	shared Safety Case methodologies for at least 10 EU countries with digital tools
Advanced nuclear deployment	Innovation / Industrial	SMR licensing & FOAK; Gen IV demo; fusion validation and development of R&I pilot facilities	Early commercial deployment and operation of ITER and other pilot fusion facilities	Large-scale fission & fusion deployment

Objectives	SET Plan Pillar	By 2030 (Short Term)	By 2040 (Medium Term)	By 2050 (Long Term)
Fuel cycle sustainability	Circularity	R&D on fuels, recycling, waste reduction	Deploy sustainable solutions	Closed fuel cycle
Waste management	Sustainability	First repository operational	Shared methods, digitalization and monitoring	EU-wide deep geological repository network
Decommissioning	Circular economy	Advanced robotics & digital tools	Industrialised sector	Circular reuse model
Medical isotopes	Health	Security of supply and reduction of import dependency	Resilient EU supply chain, domestic HALEU and stable isotopes production	Innovative therapies ecosystem
R&D infrastructure	Research	Modernise and integrate	EU-wide network	Global leadership ecosystem
Skills	Skills	EU Education &Training (E&T) framework	Harmonised qualifications and integrated E&T programs	Sustainable workforce with secure channels of E&T
Energy systems integration	System integration	Pilot projects	EU integrated systems	Optimised multi-vector system
Societal engagement	Governance	Enhanced stakeholder's engagement	Embedded in governance	Transparent and continuous dialogue

1. Introduction

1.1. Scope and purpose of the Thematic Vision

1.1.1. Scope

The Implementation Working Group (IWG) on Nuclear operates within the framework of the Strategic Energy Technology Plan (SET Plan) as the body responsible for coordinating European research, innovation and policy alignment in the field of nuclear technologies and applications (and will consider the upcoming SRIA on fusion). Its mandate encompasses the entire lifecycle of nuclear technologies—from the safe operation of existing reactors to the development of advanced systems, decommissioning, the front and back end of the nuclear fuel including radioactive waste management, and cross-cutting enablers such as digitalisation, cybersecurity, circularity and skills development. This comprehensive scope reflects the importance attributed by the European Commission and Member States to maintaining a high level of nuclear safety while improving efficiency, affordability and sovereignty.

The IWG's technological remit covers current light-water reactors operating under long-term operation conditions, as well as future reactor technologies including fast neutron-spectrum (liquid metal cooled), high-temperature, molten-salt and potentially complemented by accelerator-driven systems (ADS) dedicated to the reduction of long-lived radioactive waste. As highlighted in the SET Plan Implementation plan[9], these technologies are essential for improving resource efficiency, optimising spent fuel and radioactive waste management, and strengthening the sustainability of the fuel cycle. The group also plays an important role in facilitating coordination between Member States, regulators, industry, research organisations, academia and European institutions, in line with the revised SET Plan governance architecture—particularly the re-established Steering Group under the Net-Zero Industry Act, which aims to reduce fragmentation and strengthen alignment of policies and investments across the EU.

1.1.2. Purpose

The purpose of this Thematic Vision is to provide a strategic, forward-looking framework for the IWG's actions and priorities over the coming decade and beyond. It articulates the medium- and long-term ambitions of public authorities in relation to nuclear as low carbon stable energy source, identifies the milestones needed to achieve these ambitions, and outlines the research, innovation and policy measures required to support them.

Action in this field is necessary because nuclear energy continues to be a major contributor to Europe's climate-neutrality ambition, economic relevance, energy security and affordability, electricity grid stability and industrial resilience. Ensuring the safety, sustainability and societal acceptance of nuclear technologies—both existing and future—is therefore a political and strategic priority for the European Union. The Thematic Vision consolidates this direction, providing a coherent roadmap for aligning national and European research and innovation (R&I) agendas[10], supporting evidence-based policymaking and strengthening Europe's leadership in the nuclear sector.

[9] SET Plan documents - SETIS - SET Plan information system

[10] Nuclear investment needs - Energy - European Commission

1.1.3. Progress and recent developments in the thematic area

Recent years have seen significant political, technological and geopolitical developments that shape the relevance and urgency of coordinated action in the nuclear sector, both in terms of technologies and applications.

Recent IEA[11] and OECD/NEA[12] reports warn of a rapidly widening gap between energy demand and supply and highlighted the nuclear energy's potential contribution to closing it. The existing nuclear fleets, lifetime extension, and new-build programs -including SMRs and Advanced Modular Reactors (AMRs) -could play an important role in delivering large volumes of reliable, low-carbon power (electricity and heat) at scale. By providing consistent generation independent of weather conditions, nuclear energy can both stabilize grids increasingly reliant on renewables and significantly narrow projected supply shortfalls. A more balanced outlook would therefore recognize nuclear not as a marginal option, but as a central pillar capable of mitigating the very gap these reports highlight.

In the EU, while energy savings remain essential, the structural transformations underway -rapid electrification of transport and industry, the exponential growth of data centers and digital infrastructure, and shifting industrial patterns including both de-industrialization in some sectors and re-industrialization in others- are set to drive significant increases in electricity, molecules and heat/cooling demand. Scenarios that underestimate these dynamics risk misguiding policy and investment decisions. To remain competitive in the global economy, the EU must adopt more realistic, forward-looking frameworks that integrate resilient supply expansion, infrastructure investment, and system flexibility, ensuring that the transition is not only climate-aligned but also economically viable and supportive of industrial competitiveness.

Politically, the European Commission's revised SET Plan and its integration under the Net-Zero Industry Act underscore a renewed commitment to strategic industrial capabilities, reduced dependence on external suppliers and accelerated deployment of strategic clean-energy technologies, including nuclear.

In addition, the Nuclear Illustrative Programme (PINC) published on 10 March 2026, provided fact-based assessment of nuclear investment needs across the full lifecycle of nuclear technologies, outlining how nuclear power can contribute to climate neutrality, energy security, and industrial competitiveness in the EU and defined the investment outlook and policy considerations, ensuring that nuclear development aligns with broader EU energy transition objectives. Thus, the SET Plan, and the PINC are closely connected as complementary instruments guiding Europe's long-term energy and nuclear strategy.

Moreover, the European Industrial Alliance on SMRs operates within this broader policy environment by specifically targeting the development, demonstration, and deployment of SMRs by the early 2030s, strengthening the nuclear supply chain, supporting R&D&I, and identifying financial and regulatory enablers needed to bring SMR projects to market while optimising their EU valorisation potential. This approach is closely aligned with the SMR Strategy, which provides a targeted framework and defines nine key concrete actions to accelerate SMR deployment in Europe over the next decade, strengthen the European supply chain, streamline regulatory frameworks and address investment barriers. Recognising the potential of SMRs to provide reliable electricity as well as heat

[11] The Path to a New Era for Nuclear Energy – Analysis - IEA

[12] Nuclear Energy Agency (NEA) - 2025 NEA Annual Report

for district heating and industrial applications. The Strategy also proposes an 'SMR Coalition' of interested Member States to enhance policy, regulatory, licensing, and economic coordination for selected SMR designs. Together, the SET Plan creates the strategic innovation ecosystem, while the SMR Strategy provides strategic direction and the SMR Alliance translates this vision into concrete industrial action[13], enabling that SMRs contribute effectively to Europe's energy security, industrial competitiveness, and climate-neutrality objectives.

Technologically, the nuclear sector is undergoing a flourishing phase of rapid innovation. Existing reactors are increasingly operated under long-term operation (LTO) conditions, based on continuously enhanced ageing-management methodologies, integrity assessments and severe-accident management strategies. At the same time, Europe is investing in a diverse portfolio of advanced reactor technologies, which promise improved resource efficiency, optimising spent fuel and radioactive waste management, higher operating temperatures and enhanced flexibility for industrial applications - objectives recognised in both the Declaration of Intent and the Implementation Plan.

To accelerate the industrial deployment of fusion energy in Europe, the EU aims to adopt soon a comprehensive Fusion Strategy, with the main following goals: (a) establish a comprehensive governance at EU level; (b) build on ITER experience and continue build-up of technology infrastructures; (c) establish a public-private partnership with EU supply chain including startups; (d) create an adequate regulatory framework; and (e) ensure adequate workforce with the right skills. All this, in constant dialogue with EU stakeholders and citizens.

At the same time, delivering on the objectives of the SAMIRA Action Plan, as energy's sector contribution to Europe's Beating Cancer Plan[14] and on the REPowerEU roadmap[15], the EU aims to further strengthen the security of medical radioisotopes supply and to facilitate investments in production capacity, along the value chain, starting from domestic HALEU metallization capacities and stable isotopes towards innovative therapies and increased quality and safety of medical procedures. The upcoming launch of the European Radioisotope Valley Initiative[16] (ERVI) will further contribute to these strategic objectives.

Geopolitically, the changing global energy landscape and recent security concerns have renewed the EU's focus on strategic autonomy, supply-chain resilience and secure nuclear fuel supplies, as highlighted in the Declaration of Intent's enabling conditions (security, safeguards, diversified fuel supplies). This reinforces the importance of coordinated action across Member States to safeguard the resilience of critical nuclear infrastructures.

Despite these developments, the sector faces persistent barriers: fragmentation of regulatory and R&I approaches across Member States; gaps in digitalisation and data interoperability; shortages of specialised skills; challenges in managing societal acceptance; and slow deployment of advanced technologies, among others due to limited investments. The new SET plan organisation and accompanying measures aim to reduce this fragmentation, to promote collaboration and to spur public and private investments.

[13] https://energy.ec.europa.eu/topics/nuclear-energy/nuclear-investment-needs_en

[14] eu_cancer-plan_en_0.pdf

[15] REPowerEU – phase out of Russian energy imports - Energy

[16] SAMIRA Action Plan - European Commission

Economically, the nuclear sector is one of the cornerstones of the EU economy because it provides a stable, large-scale, low-carbon baseload energy supply while underpinning industrial competitiveness, grid stability, technological leadership, and high-skilled employment. Nuclear power consistently delivers nearly one-quarter of the EU's electricity and about half of its low-carbon electricity, making it useful for energy security and the decarbonisation of industry and households. The sector supports a robust industrial base: widely, Europe operates around 100 reactors and maintains globally competitive technological and manufacturing capabilities across most parts of the nuclear supply chain, despite strong international competition. This industrial ecosystem sustains approximately 500,000 direct and indirect jobs across the EU, many in high-tech and high-value domains, and will require up to 250,000 new skilled workers in the coming decades[17], demonstrating its long-term economic significance and strategic importance for Europe's energy sovereignty and industrial resilience.

The Important Projects of Common European Interest (IPCEI)'s design phase[18]—endorsed by the European Commission in April 2025—aims to support projects with high innovation potential and significant spillovers across the EU nuclear ecosystem, complementing the SET Plan's strategic objectives by creating the financial, regulatory, and collaborative conditions needed to bring innovative nuclear solutions to market. Together, the SET Plan shapes the strategic direction for nuclear innovation, while the IPCEI intends to operationalise that vision through structured, multi-country industrial action, enabling the EU to accelerate deployment of next-generation nuclear technologies at scale.

Importantly as well, nuclear technologies make a vital contribution to the health sector by enabling millions of medical diagnoses and treatments each year through the production and use of medical radioisotopes. These isotopes are essential for detecting cancers, cardiac conditions, and other diseases, and are increasingly used in targeted therapies, supporting around 10 million medical procedures annually in Europe[19]. EU plays a leading global role in this field, with its research reactors producing the majority of key isotopes such as Mo-99, I-131 and Lu-177 for imaging and cancer treatment, ensuring that patients benefit from advanced nuclear medicine techniques that offer high precision and rapid diagnostic capability[20]. Strengthening the resilience of the nuclear medical supply chain, while promoting regulatory harmonization will support these innovative techniques to make the clinical translation, bringing hope to cancer patients.

Moreover, nuclear energy has strong future potential to power long-endurance maritime vessels with low carbon emissions and to enable deep-space missions by providing reliable propulsion and electricity where solar power is limited.

Regulations: Innovation-friendly regulatory frameworks are essential for advancing both new and established nuclear activities, including reactor lifetime extension, decommissioning, and geological disposal. Significant opportunities exist to accelerate progress through innovation and digitalisation. The sector's digital transformation should build on early successful applications and evolve into an increasingly connected ecosystem. In particular, digital tools, such as digital twins, are expected to

[17] EHRO-N - Joint Research Centre - European Commission

[18] Joint European Forum for IPCEI - Competition Policy - European Commission

[19] https://eanm.org/publications/useful-resources/nuclear-medicine-guide/

[20] Euratom Supply Agency - Supply Agency of the European Atomic Energy Community

play a key role in supporting decision-making across new nuclear projects, decommissioning, and waste disposal activities.

Inevitably, the availability of a highly skilled, adaptable and safety-aware workforce capable of supporting the entire nuclear value chain, is of critical importance. Education is therefore a strategic enabler that supports the innovation, development, demonstration, deployment, operation and decommissioning of nuclear technologies and their various applications, as well as their associated fuel cycles, radioprotection and regulatory duties.

The EU's nuclear R&D&I landscape relies on a robust network of specialised infrastructures, including research reactors, experimental facilities, irradiation platforms, radiochemistry laboratories, and advanced testing environments that support both fission and fusion research. These infrastructures are essential for fuel development, safety testing, materials qualification, and the production of medical and industrial radioisotopes, yet many are ageing and require refurbishment or replacement to remain fit for purpose by 2030 and beyond. The EU needs consolidating its nuclear research infrastructures to improve access, coordination, and interoperability across Member States, addressing long-standing fragmentation and ensuring researchers and industry can use state-of-the-art facilities efficiently.

2. Vision and targets

2.1. Short-term (2030)

By 2030, the IWG-Nuclear aims to ascertain that Europe's nuclear fleet—including operating reactors, new builds, fuel cycle facilities, and decommissioning activities—keep improving their efficiency and operating safely according to the highest achievable safety standards. This ambition aligns with the revised (SET) Plan (2023–2026), which prioritizes continuous safety improvement, robust ageing management, advanced accident-tolerant designs, safe spent fuel management, and the deployment of innovative nuclear technologies, including SMRs and Generation IV systems. The approach of the IWG integrates recommendations across all the Task Forces (on Circularity, Digitalization, Skills, Societal Needs, and Access to Market), ensuring alignment with the objectives of the SET Plan.

2.1.1. Safety of Existing and Future Nuclear Power Plants

Consolidated Evidence for Long-Term Operation (LTO) and Ageing Management (by 2027)

By 2030, the IWG will support consolidating and harmonizing the results of extensive European R&I on robust and safe extension of the operating life of existing reactors. The aim is to promote developing a scientifically validated understanding of ageing mechanisms affecting critical structures, systems, and components (SSCs) and improving the exploitation in advanced materials behaviour predictive methodologies, blending physics-based and data-driven approaches. This process emphasizes advanced modelling, probabilistic and deterministic assessments, and improved inspection and integrity assessment methodologies as essential for the safe long-term operation of both existing and new reactors. The IWG will encourage integrating outputs from major EU and national programs, which have advanced the understanding of various degradation mechanisms, and non-destructive evaluation techniques such that EU regulators can safely license LTO projects today.

In addition, component obsolescence and repair needs associated with LTO will have to be effectively and affordably addressed through development and qualification of advanced manufacturing methods.

The IWG will also promote the use of digital twins, advanced data-driven modelling, and predictive maintenance tools for long-term performance monitoring and lifecycle management of safety-critical components.

Strengthened Severe Accident Management Capabilities (2025–2028)

By 2030, the IWG aims to target full incorporation of the results from major European and national R&D programs on severe accident phenomena into European harmonized and updated Severe Accident Management Guidelines (SAMGs) especially for advanced systems. This effort will consolidate outcomes from key national, European and international projects that have developed advanced methodologies, numerical tools, and experimental evidence to support robust severe accident mitigation strategies. The IWG will, therefore, promote the adoption of improved emergency preparedness tools and risk communication strategies strengthening Member States' capabilities in real-time emergency assessment, technical decision-making, and cross-border coordination.

2.1.2. Advancement of Innovative Nuclear Technologies: SMRs, Gen III+, Gen IV and fusion facilities

SMR Licensing Readiness and First-of-a-Kind Deployment Steps (2026–2030)

By 2030, the IWG aims to support Eu transitions from the licensing of SMR designs to the first-of-a-kind (FOAK) demonstrations. This ambition aligns with the Net-Zero Industry Act (NZIA), the SET Plan Declaration of Intent, and the SMR Strategy and the European Industrial Alliance on SMRs. which emphasize the strategic role of SMRs in achieving the EU's climate neutrality, energy security, and industrial competitiveness goals.

The IWG will pursue the promotion of a coordinated regulatory approach across Member States, leveraging mechanisms such as to increase convergence in EU Pre-Licensing Framework (2026–2030): Supported by the European industrial alliance on SMRs, the European SMRs Task Force and the IAEA's Nuclear Harmonisation and Standardisation Initiative (NHSI)[21], this framework will enable early dialogue between regulators, designers, and industry stakeholders, reducing duplication and clarifying safety and licensing requirements.

The IWG will facilitate the adoption of joint reviews, mutual reliance arrangements, and shared technical assessments among Member States. These mechanisms, already piloted in projects, are critical to reducing licensing complexity, improving regulatory convergence, and ensuring that SMR designs can be deployed efficiently across multiple jurisdictions.

Progress Toward Generation IV Demonstrators (2026–2030)[22]

By 2030, Europe's progress in next-generation nuclear technologies – advanced modular reactors (AMR) - will be characterized by technological, design and licensing advancements in fast spectrum reactors (liquid metal cooled), high-temperature reactors and molten salt reactors potentially complemented by accelerator-driven systems (ADS) dedicated to the reduction of minor actinide-containing long-lived radioactive waste. Owing to their improved fuel use, breeding and transmutation capability, the fast neutron reactors in a nuclear fleet together with the required processing facilities is intended to vastly improving the sustainability of a nuclear energy system. This is why the EU is supporting safety analysis and technology aspects (e.g., material studies) of different fast reactor types, including their modular versions based on sodium, lead or molten salts. Euratom projects and national programmes are delivering critical data, methods, and modelling tools to support safety and feasibility assessments as well as pre-licensing activities. The maturation of high-temperature gas-cooled reactors (HTGRs) continues through coordinated efforts in safety demonstration, thermal-hydraulic modelling, fuel and component qualification.

This work is accompanied by techno-economic studies to optimise energy system integration and to minimise cost. These reactors could become complementary to other advanced reactor designs, in particular for industrial heat applications and energy system integration with renewables, aligning with the NZIA's emphasis on decoupling industrial processes from fossil fuels and enhancing the EU's strategic autonomy in clean energy technologies. To accelerate the deployment of AMRs in the EU market, requires a rapid change of paradigm toward accelerated materials development and

[21] Nuclear Harmonization and Standardization Initiative (NHSI)

[22] download

qualification, intelligent health monitoring systems, advanced predictive methodologies and effective knowledge-management frameworks.

The European Industrial Alliance on SMRs and the Net-Zero Industry Act both highlight the need to:

- Strengthen the EU's nuclear supply chain, ensuring sovereign capacity for fuel cycle services, component manufacturing, and advanced materials production;
- Foster cross-sectoral innovation, particularly in digitalization, AI, and advanced manufacturing, to enhance the competitiveness of European nuclear technologies on the global stage;
- Test regulatory Sandboxes: Inspired by the EU's broader push for innovation-friendly regulatory environments, these controlled testing environments will allow for real-world validation of AMRs safety claims and early resolution of cross-border licensing challenges.
- Support Net-Zero Strategic Projects, prioritizing investments in SMRs, R&D&I for AMRs, and advanced fuel cycles as essential to the EU's resilience and long-term energy security.

Towards commercial fusion energy deployment in the EU

The EU's vision for fusion R&D is to maintain the position of Europe as a global leader in developing safe, sustainable, and commercially viable fusion energy by building on its long-standing scientific leadership and major investments such as the International Thermonuclear Experimental Reactor (ITER)[23]. The EU goals is to include strengthening the industrial fusion ecosystem, developing a skilled workforce, and establishing an enabling regulatory and investment framework to bring fusion energy from laboratory research to commercial deployment in the coming decades. To accelerate fusion commercialisation, the European Commission has requested ENSREG and the ENSREG Task Force on Fusion Energy to develop recommendations on the need for a specific EU legal framework on fusion (due in 2027). In 2026 the Commission is also planning to establish a co-programmed Public-Private Partnership (PPP) through two key initiatives: the European Fusion Stakeholder Platform (EFSP), representing industry and research organisations, and the industry-led association FUSION NOW, which will sign the PPP's Memorandum of Understanding (MoU) with the European Commission. FUSION NOW will co-develop the Strategic Research and Innovation Agenda (SRIA), incorporating input from the EFSP, to guide funding calls and strategic priorities for fusion energy development. In parallel, investments in the construction ITER and IFMIF-Domes continue in order to demonstrate material compatibility and self-sustaining burning plasma by the mid-2030s.

2.1.3. Radioactive Waste Management, Spent Fuel, and Decommissioning: Advancing Europe's Nuclear Sustainability and Circularity

First Deep Geological Repository for spent nuclear fuel Operational in Europe (by 2025–2030)

The former SET Plan's Declaration of Intent established a preliminary milestone for Europe's radioactive spent fuel and waste governance: the operation of the continent's first deep geological repository (DGR) for spent fuel by 2025. Finland's Onkalo repository is now being built and

[23] ITER - the way to new energy

demonstration activities have been carried out, so that actual disposal operations can start in 2026/2027, setting a global benchmark for geological disposal safety and governance. Sweden's Forsmark DGR received its construction license in 2024, while France's Cigéo project is advancing toward operational readiness.

Facilitating these national milestones is among others (national and international programmes) the European Joint Programme on Radioactive Waste Management EURAD-2[24] that is acting the primary vehicle for European R&D cooperation. EURAD-2 coordinates a unified research roadmap between Waste Management Organizations (WMOs), Technical Support Organizations (TSOs), and research entities. By integrating the technical advancements from 'front-runner' programs, such as Onkalo and Cigéo, with the needs of Member States in earlier development phases. EURAD-2 ensures a continuous transfer of safety-critical knowledge and optimizes the management of both legacy and future waste streams from cradle to grave. At the same time, waste minimisation and adoption of circular economy practices would also strengthen the EU's strategic autonomy, fostering domestic innovation and sustainability across the nuclear value chain, among others by applying fuel reprocessing and recycling.

By 2030, the IWG aims to foster collaboration among national and international stakeholders to consolidate a technically and scientifically robust foundation for spent fuel and radioactive waste management, primarily through the implementation of the EURAD-2 roadmap and in alignment with the ongoing revisions of the 2006 and 2011 Euratom Directives[25]. These efforts focus on refining Safety Case methodologies, converging monitoring strategies, and strengthening technical expertise sharing among Member States.

World-Leading Decommissioning Capability by 2030

Europe is committed to achieving a world-leading decommissioning capability by 2030, ensuring that dismantling activities are conducted safely, efficiently, and sustainably. Progress toward this objective is supported by the integration of advanced radiological characterization and classification methods, including robotics, remote handling solutions, and digital simulation tools, which enhance operator safety and optimize dismantling workflows.

The International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA) have highlighted the increasing adoption of digital tools, virtual reality, and autonomous robotic systems in decommissioning operations[26]. By 2030, these technologies will be standard practice, enabling precise planning, real-time monitoring, and cost-effective execution of decommissioning projects.

The advancement of Europe's decommissioning and waste management capabilities is fully embedded in the EU's broader industrial and circular economy strategies, as articulated in the Circular Economy Act (expected 2026), the Net-Zero Industry Act (NZIA), and the Clean Industrial Deal. These frameworks emphasize:

- In waste management and disposal, greater harmonisation of radiological, environmental, and circularity-related regulations is essential to achieving the long-term vision. Dedicated

[24] Homepage | Eurad

[25] Radioactive Waste Directive (2011/70/Euratom) and the Directive on shipments of radioactive waste and spent fuel (2006/117/Euratom)

[26] Nuclear Energy Agency (NEA) - NEST Advanced remote technology and robotics for decommissioning (ARTERD)

R&D should provide the scientific basis for this alignment, enabling more balanced, socially acceptable solutions and, where appropriate, the development of joint approaches across Member States.

- Enhancing cross-border cooperation and knowledge-sharing through platforms like the SNETP, IGD-TP, and others, ensuring that best practices and technological advancements are disseminated across Member States;
- Supporting Net-Zero Strategic Projects, prioritizing investments in advanced decommissioning technologies, circular material use, and sustainable waste management solutions as essential to the EU's resilience, competitiveness, and climate neutrality goals.

By 2030, the advancement of geological disposal expertise and the modernization of decommissioning technologies -coupled with the integration of circularity and digital innovation- will enable Europe to meet its 2030 ambitions while reinforcing public confidence and ensuring the highest standards of nuclear safety and sustainability.

2.1.4. Skills, Safety Culture, and Societal Integration in the European Nuclear Sector

European Nuclear Skills Framework (2026-2028)

In line with the SET Plan Cross-Cutting Task Force on Skills and the European Union of Skills initiative, the IWG will prioritize a rapid upgrade of Europe's nuclear skills base and continuous training programs tailored to lifetime extension contexts, digital instrumentation and control, predictive maintenance, and safety management systems. These programs will ensure that existing staff acquire the new capabilities required for modernized plants and that organizations can demonstrate sustained competence as part of safety cases and periodic safety reviews.

Enhanced cooperation between universities, technical institutes, research organizations, industry, regulators and public authorities can support the development of common educational standards, shared curricula, joint degrees, micro-credentials, professional certifications and qualifications throughout Europe and ensure that graduates possess the knowledge and skills required by employers across the nuclear sector.

R&D infrastructure to consolidate the nuclear sector leadership of the EU (2026-2030)

By 2030, the EU must address significant challenges in maintaining and modernising the infrastructures that underpin nuclear R&D. Many essential facilities -particularly research reactors, isotope-production facilities, and experimental testing installations- are ageing and face refurbishment or replacement needs to prevent supply disruptions and ensure the continuity of critical research activities. At the same time, Europe's research infrastructure landscape remains fragmented, with uneven accessibility, limited interoperability and profitability, and insufficient coordination across Member States, which hinders collaboration and slows innovation. Consolidation efforts, such as grouping critical infrastructures and open access, are needed for stronger integration with sustainable funding, and modernised experimental platforms to remain at the forefront of nuclear safety, advanced reactor development, and radioisotope production by 2030.

Integrated energy systems and techno-economic coordination across Scales (2026-2030)

Energy system integration and techno-economic optimisation involve coordinating diverse energy sources (renewables, nuclear, and fossil with CCS), networks (electricity, gas, and both district and industrial heat), storage solutions, and end-users into a coherent and flexible system across multiple

scales: from industrial sites (e.g. coupling electrification, process heat, hydrogen production, and onsite generation), to regions and national grids, up to EU-wide interconnected markets. This integrated approach enables cost-efficient decarbonisation by balancing variability, maximising asset utilisation, and aligning supply with evolving demand patterns such as those from industry, mobility, and data centres. As a foundation , such a framework should emphasise system-level value over siloed technology pathways. To avoid duplication, collaboration with international organisations can build on the IEA's system modelling and scenario analysis, the NEA's expertise in nuclear integration and economics, and the IAEA's tools for integrated energy planning and infrastructure development, through coordinated work programmes, shared datasets, and harmonised analytical methodologies.

Enhanced Stakeholder Engagement and Social Acceptance (2026-2030)

By 2030, the IWG will make sure that societal expectations (in line with the SETplan task force recommendations) are systematically embedded into nuclear sector planning, implementation, and long-term governance. This includes the systematic integration of citizen and local community engagement into three major categories of activities:

- Deployment of Small and Advanced Modular Technologies (SMRs/AMRs): continuous citizen engagement will clarify benefits, risks, siting criteria, and socio-economic implications over a long term dialogue;
- Development and long-term governance of deep geological disposal facilities: early and ongoing involvement of communities will be fundamental to public confidence and project durability;
- Projects extending the operating lifetime of existing reactors (LTO): Systematic transparent, open dialogue and engagement with local populations in order to understand the safety case, ageing management strategies, and long-term environmental considerations.

The European Nuclear Safety Regulators Group (ENSREG) and the OECD Nuclear Energy Agency (NEA) emphasize that integrating societal perspectives strengthens acceptance, accountability, and resilience in nuclear energy systems.

R&D Challenges for the Health Sector by 2030 in Nuclear Technology

A central challenge is securing a stable, long-term supply of medical radioisotopes, which are essential for millions of diagnostic and therapeutic procedures in Europe every year The health sector faces several critical R&D challenges linked to nuclear technologies, especially due to rising demand for medical radioisotopes and the ageing infrastructure (research reactors) that currently supplies them. At the same time, the EU relies on imports of strategic inputs such as HALEU fuel and stable isotopes (Ytterbium 176 for e.g.). The REPowerEU roadmap calls for the creation of ERVI in order to secure EU supply of medical radioisotopes through increased own production. . Ensuring new domestic production capacity across the entire value chain remains a key priority, requiring coordinated R&D efforts and implementation.

Another major challenge is advancing innovation in radiopharmaceuticals, where the need for new therapeutic isotopes and next-generation cancer treatments is rapidly increasing (like FLASH radionuclide and targeted ALPHA therapies). This includes improving radiochemistry processes, developing more efficient isotope-production methods, and securing source materials across the supply chain and integrating recycling of target materials to increase strategic autonomy.

Additionally, the sector must address skills shortages and workforce renewal, as expertise in nuclear medicine, radiochemistry, and reactor operations is essential to sustaining medical-isotope production

and deploying advanced nuclear technologies. EU institutions have already highlighted the urgent need to develop specialized skills to maintain leadership in nuclear-medicine innovation.

Finally, modernizing regulatory frameworks for transporting, producing, and applying radiopharmaceuticals remains an R&D-linked challenge. Regulatory processes must evolve to support rapid, safe logistics across the EU. Research is needed to optimize treatment qualification, radiation protection standards, quality assurance, and cross-border isotope transport mechanisms, building on and aligning with existing European initiatives such as the SAMIRA Action Plan and the forthcoming ERVI communication, which aim to strengthen the security, resilience, and coordination of medical radioisotope supply chains across the EU.

2.2. Medium-term (2040)

By 2040, the IWG envisions that the EU will have an optimised, integrated and technologically advanced nuclear system, fully aligned with the strategic objectives outlined in the revised SET Plan governance, the Net-Zero Industry Act (NZIA), PINC and SMR Strategy. This transformation will reflect Europe's commitment to establishing a nuclear sector that is not only safe and more sustainable but also strategically autonomous, contributing significantly to the continent's climate neutrality, industrial competitiveness, and energy resilience.

Politically, a significant part of the Europe's nuclear eco-system should operate under a fully integrated, transparent, and modernized safety framework by 2040. This framework should be informed by robust research outputs and coordinated policy alignment across Member States, building on the SET Plan's emphasis on reducing fragmentation and strengthening governance.

At the technological level, Europe aims to achieve a high degree of maturity in next-generation nuclear systems by 2040. These systems, supported by extensive research and innovation efforts throughout the 2020s and 2030s, should be ready for early commercial deployment. Improved uranium-resource efficiency is becoming urgent at middle-term strategic goals, reinforcing the importance of advanced modular reactor technologies

In parallel, the expanded use of digital tools and interoperable data platforms will strengthen reporting mechanisms and repository governance. Greater transparency, together with enhanced safety, security, and safeguards oversight, altogether with more interdisciplinary research and activities, including social sciences and the humanities will foster public trust and support the robustness of safety cases. Europe Member States should have consolidated shared Safety Case methodologies, long-term monitoring strategies, and cross-border cooperation frameworks. At the same time, innovative waste management practices should be developed to include next-generation nuclear systems in a sustainable way.

Europe's ambition to build a world-leading decommissioning sector by 2030 will, by 2040, translate into a fully industrialized capability. This capability will rely on advanced radiological characterization techniques, robotics, remote handling, digital simulation, and optimization tools derived from the Implementation Plan's research and innovation activities. Consistent with the circularity Task Force recommendations, decommissioning practices will also incorporate large-scale reuse of infrastructures, recycling of materials, and/or substitution of critical substances (if any), aligning dismantling operations with the broader EU resource-efficiency strategy.

Finally, by 2040, the transformation of skills, digital, and societal ecosystems, ensuring the long-term resilience, legitimacy, and excellence of the nuclear sector should be consolidated. These capabilities will be fully embedded through harmonized qualifications, mobility tools, and continuous training

mechanisms. The societal expectations—equity, accessibility, transparency, and community engagement—should be structurally integrated into nuclear decision-making. By 2040, these principles are expected to shape all major nuclear programs, including lifetime-extension projects, advanced reactor deployments, and long-term waste-governance strategies.

2.3. Long-term (2050)

By 2050, IWG envisions a fully mature, and integrated, European nuclear system that combines the highest achievable levels of safety with strategic autonomy, climate neutrality, and technological leadership. This long-term vision extends beyond fission-based technologies to include fusion energy, which is expected to play a transformative role in Europe's energy landscape by mid-century.

By 2050, Europe should operate a shared Safety Case methodologies where safety assessments, are standardized across most Member States. By mid-century, Europe's nuclear fleet should be supported by data-driven, digitalized, and predictive safety tools, enabled by decades of progress in digital twins, shared data infrastructures, high-performance simulation platforms, and cyber-secure operational environments. These advancements should ensure that safety demonstrations are robust, transparent, and adaptable to evolving technological and societal needs.

A major long-term political goal for 2050 is the deployment at meaningful scale of a selection of advanced nuclear technologies, including either fast-spectrum reactors, high-temperature reactors, molten salt reactors, or accelerator-driven systems. This vision also includes the consolidation of a closed fuel cycle capability, supported by decades of research and development in separation, transmutation, and advanced fuel fabrication technologies, including for HALEU, ensuring that Europe's nuclear energy system is both efficient and sustainable. Additionally, fusion energy is expected to emerge as a critical component of Europe's energy mix in the next two decades[27]. By 2050, the EU envisions the private sector leading the deployment of commercial fusion power plants, building on the technical validation and industrial capabilities developed in the preceding decades. By 2050, at least some of these systems, are expected to have reached commercial maturity, contributing flexibly to both electricity generation and industrial applications, thereby supporting the EU's broader decarbonization objectives.

Spent fuel and radioactive waste management will be a defining pillar of Europe's nuclear landscape by 2050. A key priority will be the implementation of an integrated approach to radioactive waste management, ensuring that disposal pathways are identified and established before waste is generated. By 2050, the ambition is to have a network of deep geological repositories operating across Member States. It should also include joint solutions across the waste management chain, such as melting facilities, interim storage facilities, surface disposal facilities, and geological disposal solutions. These facilities will be supported by similar Safety Case methodologies and aligned monitoring approaches, with safety assessments underpinned by advanced sensor technologies, real-time digital monitoring, and interoperable EU-wide data platforms.

[27] [Text to be aligned with the upcoming EU Fusion Strategy after adoption in 2026]

3. Conclusions and next steps

This Thematic Vision sets out a coherent, ambitious pathway for the future of nuclear energy and applications in Europe. It confirms that nuclear technologies—spanning energy generation, industrial processes, health, research, maritime and space applications—remain essential to achieving the European Union's long-term objectives in climate neutrality, energy security, industrial competitiveness, and strategic autonomy.

By integrating safety, sustainability, innovation, and societal considerations across short-, medium-, and long-term horizons, the Vision reinforces the role of the IWG as a central coordinating platform under the SET Plan. It demonstrates that continuous improvement of existing reactors, responsible deployment of SMRs and advanced systems, robust spent fuel and waste management solutions, world-leading decommissioning capabilities, and sustained investment in skills and infrastructures are not isolated challenges but mutually reinforcing pillars of a resilient nuclear ecosystem.

The Vision also highlights that success will depend on strengthened cooperation among Member States, regulators, industry, research organisations, academia, and civil society. Regulatory convergence, shared safety evidence, open and modern research infrastructures, and transparent stakeholder engagement are critical enablers for timely deployment and public confidence. Equally, attracting and training the next generation of nuclear professionals is indispensable to sustaining Europe's leadership and ensuring operational excellence over the coming decades.

Looking towards 2050, the IWG's Vision positions Europe to benefit from both advanced fission and fusion energy, and support commercial power plants ensuring that nuclear technologies can flexibly support decarbonised electricity systems, low-carbon industrial transformation, and emerging strategic non-power applications. By providing a stable and credible strategic framework, this document aims to guide coordinated action, mobilise investment, and translate Europe's scientific and industrial strengths into lasting societal and economic value.