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Advanced Materials

Group of Chief Scientific Advisors

Independent Expert Report

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April 2026

Advanced Materials

Group of Chief Scientific Advisors

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EUROPEAN COMMISSION

SCIENTIFIC ADVICE MECHANISM

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(Supported by SAPEA Evidence review Report)

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Executive Summary

Our society is fundamentally reliant on advanced materials. They underpin infrastructure, digital technologies and everyday consumer products, and they are essential enablers of the objectives set out in the European Green Deal¹. On a functional level, advanced materials are designed to contribute to buildings that last longer, electronic devices that can be integrated to the human body, and drugs that are delivered with accuracy and precision. They have the potential to enhance resilience and defence, support sustainable economic growth driven by research, innovation and skills, and strengthen strategic autonomy through the recycling and substitution of critical raw materials. To deliver on these ambitions and secure prosperity in Europe, the need to prioritise development of materials that will accelerate the green energy transition is particularly urgent. But an element of caution would be wise: history shows that insufficient toxicological testing of materials risks introducing environmental and health hazards with long-lasting impacts.

The European Commissioner for Startups, Research and Innovation Ekaterina Zaharieva asked the Group of Chief Scientific Advisors (GCSA) to the European Commission to provide a Scientific Opinion addressing advanced materials. This opinion was prepared by the GCSA in collaboration with the Science Advice for Policy by European Academies (SAPEA) network and a secretariat within the Directorate-General for Research and Innovation (DG RTD), which together constitute the Scientific Advice Mechanism (SAM). The Opinion addresses two questions set out in the scoping paper: first, it identifies research areas in which Europe has established strengths and high impact potential, as well as gaps requiring further EU efforts to advance key ambitions such as Europe's sustainable prosperity and growth, or defence and security, and second, it outlines mechanisms to enhance cross-sectoral exchange, strengthen links between basic research and industrial uptake, and support new business models aligned with performance-based standards.

This Opinion is built on the conviction that prioritising core EU values such as safety, sustainability, transparency and high production standards will enable the advanced materials sector to become a key driver of European competitiveness, reinforcing investor and consumer trust, supporting Europe's long-term autonomy, and contributing Europe's geopolitical resilience. Delivering this change requires investing in the construction of an effective advanced materials ecosystem, where research and manufacturing, technological development, regulation, product

¹ [Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – The European Green Deal COM \(2019\) 640 final](#)

design, and optimal recycling and reuse are all closely connected throughout the value chain. Once in place, this ecosystem will enable accelerated and responsible innovation, yielding long-term benefits. Success will depend on broad stakeholder engagement, coordinated action, flexibility and sustained strategic foresight.

The challenges outlined in this Opinion are substantial, but they are not insurmountable, and Europe is uniquely placed to turn them into a source of long-term advantage. We start from a position of strength: world-class research institutions and infrastructures; leading roles in metrology, standards and regulation; demonstrated excellence in databases and digital tools; and a clear set of values that place sustainability, human rights and precaution at the core of policy. Advanced materials are already central to the European Green Deal, the twin green and digital transition, and strategic autonomy agendas. With deliberate choices, they can also become a catalyst for new forms of cooperation between science, industry, regulators and society.

The Recommendations in this Opinion provide the elements of a coherent strategy to address the scoping questions.

The Overarching Recommendation presents the overall ambition, anchoring advanced materials explicitly in EU values and societal priorities, and turning safety, circularity and social responsibility into design targets.

Recommendation 1 harnesses computational and data-driven methodologies so that AI, Digital Twins and self-driving labs can accelerate discovery while improving early risk screening and ensuring that the resulting materials, products and processes are safe and sustainable.

Recommendation 2 uses Europe's comparative advantage in standards and digital product passports to create clear, performance-based rules and transparent information flows that reward durable, repairable, low-toxicity materials and could make high-quality European products a global benchmark.

Recommendation 3 focuses on turning successful research into marketable products, coordinating infrastructures, partnerships, procurement and circular business models, and helping ensure that promising materials move rapidly into sustainable, certifiable production systems.

Recommendation 4 complements this by reinforcing Europe's long-term capacity in blue-sky research and human capital, while also securing access to critical raw materials and affordable green energy, in a more coherent research and innovation (R&I) funding landscape.

If all of these recommendations are implemented together and monitored through instruments such as a Materials Impact Observatory (R3.5), these measures could turn the roadblocks of today into the stepping stones of tomorrow. They would help

Europe move from isolated pilot successes to a systematic “fast track” approach, where advanced materials move from theoretical idea to real-world impact in ways that are scientifically robust, economically competitive, safe, and socially legitimate. The goal is to eliminate risks as far as possible, and to manage unavoidable risks in a manner that is transparent, fair, and in keeping with Europe’s shared values, as a source of competitive advantage.

In this sense, advanced materials are more than a technological development. They are an opportunity to align science, policy and industry around a common long-term horizon: a resilient, climate-neutral, digitally enabled economy in which materials are designed, produced, used, recovered, and reused in ways that respect planetary boundaries, protect public health, and reinforce strategic autonomy. With the right governance, data, infrastructures and incentives in place, the EU can ensure that advanced materials become a cornerstone of sustainable prosperity.

Europe now has the chance to prove that cutting-edge innovation and long-term responsibility are not opposing forces. By deploying advanced materials science to develop competitive products without compromising ecosystems, ethics or future generations, Europe can set a global reference point benchmark for sustainable innovation and responsible industry worldwide. This is an opportunity for Europe to strengthen its competitiveness, autonomy, and prosperity by displaying technological leadership in keeping with European values.

Introduction

Our society is fundamentally reliant on advanced materials. They underpin infrastructure, digital technologies and everyday consumer products, and they are essential enablers of the objectives set out in the European Green Deal. Advanced materials can enhance resilience and defence, support sustainable economic growth driven by research, innovation and skills, and strengthen Europe's strategic autonomy by substituting critical raw materials. On a functional level, advanced materials are designed to contribute to buildings that last longer, electronic devices that can be integrated into the human body, and drugs that are delivered with accuracy and precision (SAPEA, 2026). To realise these ambitions and secure prosperity in Europe the need to prioritise development of materials that will accelerate the green energy transition is particularly urgent.

This Opinion is built on the conviction that prioritising core EU values such as safety, sustainability, transparency and high production standards will enable the advanced materials sector to become a key driver of European competitiveness, reinforcing investor and consumer trust, supporting Europe's long-term autonomy, and contributing Europe's geopolitical resilience. Delivering this change requires investing in the construction of an effective advanced materials ecosystem, where research and manufacturing, technological development, regulation, product design, and optimal recycling and reuse are all closely connected throughout the value chain. Once in place, this ecosystem will enable accelerated and responsible innovation, yielding long-term benefits. Success will depend on broad stakeholder engagement, coordinated action, flexibility and sustained strategic foresight.

Safety is a non-negotiable requirement Historical examples demonstrate that some new materials initially perceived as benign may later reveal significant risks. Polycarbonate, widely used for its robustness and transparency, was later found to leach bisphenol A (BPA), an endocrine-disrupting substance now banned from food-contact materials for children. Perfluorooctanoic acid (PFOA), formerly present in non-stick cookware, textiles and firefighting foams, has since been associated with carcinogenicity and long-term environmental persistence. These cases underscore a key challenge. Europe needs to deliver a new competitive advanced materials ecosystem, while also prioritising the social, economic and environmental concerns of its citizens, and safeguarding their health.

For Europe, advanced materials represent a significant opportunity for **industrial leadership and strategic autonomy**². The goal is to discover, scale and manufacture advanced materials within Europe, ensuring secure access to safe and sustainable supplies or substitutes for critical raw materials. Delivering on this

² [Advanced Materials for Industrial Leadership - Research and innovation](#)

will stimulate innovation and enable the substitution of materials that are rare, difficult to source or strategically vulnerable.

This Opinion addresses two scoping questions. The **first** question aims at identifying research areas that contribute to EU competitiveness, taking into account challenges related to safety and sustainability. The **second** question seeks to understand how to enhance cross-sectoral exchange, strengthen links between basic research and industrial uptake, and support new business models.

Throughout this process, **sustainability and safety have served as foundational principles.** These principles informed the identification of barriers and best practices for circularity, the assessment of opportunities and challenges arising from digitalisation and AI, and the examination of governance models required to meet Europe's long-term objectives.

This Opinion is grounded in the view that Europe's strengths in standards and regulation are central to the development and impact of advanced materials and can reinforce Europe's industrial competitiveness, provided that materials produced elsewhere are required to meet the same standards as a condition to access to the EU market. Standards shape innovation. When they reflect performance, sustainability and economic realities, they support public trust, promote market uptake and contribute to Europe's industrial transformation (Trump, B. et al., 2023).

At present, however, existing standards, methodologies and regulatory practices do not always align with this ambition. This limits Europe's ability to identify and prioritise materials that can most effectively accelerate the green and digital transitions, reduce external dependencies and be competitively manufactured within the EU. Europe requires clear and consistent guidelines for evaluating environmental, social, economic and circularity risks and opportunities across the life cycle of materials and products (Hunt et al., 2025; Soeteman-Hernandez et al., 2023; Subramanian et al., 2023).

The Opinion therefore examines practical measures to support such development. These include adapting digital product passports to enhance traceability, inform substitution decisions and strengthen recycling and reuse. They also include promoting FAIR+ (Findable, Accessible, Interoperable, Reusable, plus additional safeguards for responsible data governance) principles and implementing controlled or tiered access to materials-related data to balance transparency with adequate protection of innovation incentives. Current business models and innovation practices do not consistently prioritise these objectives (Stoycheva et al., 2025), indicating that additional EU-level incentives or regulatory measures may be required.

The Opinion recommends the **development of consensual metrics** and improved access to reliable data on a broad range of criteria relevant to life cycle analysis. These steps are essential to address diverse stakeholder interests, which may diverge or conflict. Effective solutions will require transparent governance and multi-criteria decision-making frameworks that take into account autonomy, sustainability performance, supply risk and substitutability, existing EU capabilities, dual-use potential, manufacturability, time to market and prospects for uptake.

Finally, the Opinion acknowledges that the global geopolitical context is volatile and, in several respects, unprecedented. Access to key resources, including critical raw materials and energy, may shift rapidly and unpredictably. While such developments cannot be precisely forecast or controlled, they directly influence the feasibility and resilience of technological progress. In this context, diversification of supply chains, enhanced material retention within the EU and stronger recycling and circular-use strategies will become increasingly important³. These considerations are embedded throughout the recommendations as essential safeguards for a resource-constrained future. EU policy responses to global developments may change rapidly, and continued monitoring will therefore be necessary to ensure ongoing alignment with the needs of advanced materials development.

The resulting vision reflects core EU values which include sustainability, cooperation and fairness and is rooted in the principle that science-based policymaking will underpin long-term resilience. Although advanced materials will continue to evolve, these principles should remain stable to ensure that recommendations retain their relevance and continue strengthening Europe's strategic autonomy.

³ The USA for example is taking significant action in this area, with USD 12 billion being set aside to stockpile critical raw materials [Introducing Project Vault, a critical mineral stockpile for American businesses – The White House](#)

Policy background

Advanced materials can be found in many sectors and, as a result, many EU policy areas are involved, from health, biotechnology, agriculture, employment and industrial policy to the EU's policies for external action. The 2026-2027 Work Programme for Horizon Europe, the EU's seven-year research programme, contains dedicated envelopes for advanced materials⁴. Advanced materials play an important role in policies and strategies like the Circular Economy Action Plan⁵, the Clean Industrial Deal⁶, the Critical Raw Materials Act⁷, the Chips Act⁸, the Competitiveness Compass⁹ and, more generally, for the strategic autonomy goals of the EU.

The strategic autonomy of the EU is a relatively new concept and can be traced back to two major developments – the COVID-19 pandemic, and Russia's war of aggression against Ukraine. Both events exposed the risks that highly concentrated supply chains and overreliance on a single country can pose for the European economy. The EU has responded with a new drive to identify major sources of vulnerability and safeguard access to critical raw materials and strategic raw materials through actions like Preparedness Union¹⁰, the Critical Raw Materials Act, the Resource EU Action Plan¹¹, and the coming Circular Economy Act. Advanced materials are identified as a high-risk dependency in the 2025 Commission Communication on Strengthening EU economic security¹².

⁴ https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2026-2027/wp-1-general-introduction_horizon-2026-2027_en.pdf

⁵ [Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions - A new Circular Economy Action Plan for a cleaner and more competitive Europe COM \(2020\) 98 final of 11 March 2020](#)

⁶ [Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – The Clean Industrial Deal: A joint roadmap for competitiveness and decarbonisation COM/2025/85 final](#)

⁷ [Regulation \(EU\) 2024/1252 of the European Parliament and the Council of 11 April 2024 establishing a framework for ensuring a safe and sustainable supply of critical raw materials,](#)

⁸ [Regulation \(EU\) 2023/1781 of the European Parliament and of the Council of 13 September 2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem and amending Regulation \(EU\) 2021/694 \(Chips Act\)](#)

⁹ [Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Competitiveness Compass for the EU COM\(2025\) 30 Final](#)

¹⁰ [Joint Communication to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on the European Preparedness Union Strategy Join \(2025\) 130 final](#)

¹¹ [RESourceU Action Plan – Accelerating our critical raw materials strategy to adapt to a new reality](#)

¹² [Joint Communication to the European Parliament and the Council – Strengthening EU economic security.](#)

The place of advanced materials in the EU economy continues to grow, as they can play a central role in the green, digital and just transition and are needed to drive and sustain the competitiveness of European industries. As they have the potential to substitute or reduce the need for certain critical raw materials, they are essential for the EU to deliver on its 2030 defence readiness objectives and are a key component in driving innovation for clean energy technologies¹³.

Three major reports on the future of Europe all refer to the need to safeguard these technologies. The Draghi report (Draghi, M. 2024) underlines the importance of increase funding and building new partnership for advanced materials, the Letta report (Letta, E. 2024) on consolidating the internal market stresses the urgency of addressing investment gaps, increasing funding and building new partnerships for advanced materials, and the Niinistö report (Niinistö, S. 2024) on security recalls their importance in the context of dual use and defence technologies.

In line with the conclusions of the Draghi report, competitiveness is becoming a key element in Europe's R&I strategy. In January 2025, the European Commission presented the Competitiveness Compass which focuses on 3 objectives: closing the innovation gap, decarbonising our economy and reducing dependencies. This was followed in May 2025 by the Council adoption of a policy agenda for the European Research Area, endorsing a "comprehensive roadmap for enhancing Europe's research and innovation ecosystem"¹⁴.

The Advanced Materials Act

Pressure has been building in recent years for more EU action in the area of advanced materials. In 2022, a group of key stakeholders signed an Advanced Materials 2030 Manifesto¹⁵, triggering major discussions around the role such materials could play as a driver for prosperity, with hundreds of stakeholders subsequently joining the Advanced Materials Initiative¹⁶. The following year, "Advanced Materials for Industrial Leadership" became a priority for the Commission, with the adoption of a Communication on Advanced Materials for Industrial Leadership in February 2024, setting out a strategy to create a dynamic, secure and inclusive ecosystem for advanced materials in Europe, with 14 actions and an indicative timetable for their implementation.

¹³ [Joint Communication to the European Parliament, the European Council and the Council – Preserving Peace – Defence Readiness Roadmap 2030](#)

¹⁴ [Council Recommendation of 24 June 2025 on the European Research Area Policy Agenda 2025-2027](#)

¹⁵ [advanced-materials-2030-manifesto.pdf](#)

¹⁶ https://research-and-innovation.ec.europa.eu/document/download/0fcf06ea-c242-44a6-b2cb-daed39584996_en

The Communication centres round four major challenges faced by Europe in this area: the fragmentation of R&I ecosystems, the gap between EU and US private investment in the advanced materials sector, low digitalisation levels in the design and development of advanced materials, and a lack of the necessary skills for the future.

One of the main initiatives presented in the Communication is already in place – a Technology Council for Advanced Materials to coordinate relevant R&I policies, with representatives from research and industry ministries, R&I stakeholders, and the European Commission¹⁷.

The Communication also launched a public-private partnership on advanced materials designed to deliver materials and technologies fit for the circular economy: Innovative Advanced Materials for Europe (IAM4EU)¹⁸ is expected to unlock private capital and effectively double the Commission’s budget of EUR 250M for 2025-2027 in this area.

The legislative framework for advanced materials is also evolving. In her mission letter¹⁹ of September 2024, Commissioner Zaharieva was tasked with putting forward an Advanced Materials Act to “support the research and innovation process through to manufacturing and deployment.” The legislative act is currently under development.

Safe and sustainable advanced materials for the circular economy

In 2022, to help promote research and innovation for safer and more sustainable chemicals and materials, the Commission launched a framework to ensure that chemicals and materials are safe and sustainable by design” (SSbD)²⁰. The framework is a voluntary approach to guide innovation processes so as to substitute or minimise the production and use of substances of concern, and to minimise impacts on health, climate and the environment during sourcing, production, use and end-of-life treatment. The framework was updated in 2025²¹. The Advanced Materials Communication promotes this framework, which aims to drive innovation to design and develop from a life cycle perspective.

The EU defines the following five key steps in the process:

¹⁷ [Technology Council for Advanced Materials](#)

¹⁸ [IAM4EU Partnership | IAMmaterials m-l](#)

¹⁹ [Mission Letter to Ekaterina Zaharieva](#)

²⁰ [Commission Recommendation \(EU\) 2022/2510 of 8 December 2022 establishing a European assessment framework for ‘safe and sustainable by design’ chemicals and materials](#)

²¹ [JRC Publications Repository - Safe and Sustainable by Design Chemicals and Materials. Revised framework \(2025\)](#)

- Hazard assessment of the chemical or material (chemical risk assessment, CRA)
- Evaluation of human health and safety during production and processing
- Assessment of health and environmental aspects in the final application
- Environmental sustainability assessment, and
- Social and economic sustainability assessment

A full environmental sustainability assessment considers resource extraction, energy use and end-of-life recycling, while the social and economic assessment examines supply-chain ethics and long-term affordability. Together, these steps show how SSbD steers innovation toward materials that are not only high-performance, but are also safer, more circular and more socially responsible, helping advanced materials deliver on their promise.

The framework is intended to become a global reference for innovation in pursuit of the green industrial transition, where the use of sustainable resources and feedstock to produce chemicals and materials is promoted, driving R&I investments in the proposed direction. After an initial testing period, the framework is currently under revision, with an updated version due for release in the first quarter of 2026.

Following on from the Circular Economy Action Plan of March 2020, the Commission is now working on a Circular Economy Act²², expected for autumn 2026. Circular economy is one of the main building blocks of the European Green Deal, Europe's agenda for sustainable growth, and a key mechanism for reducing pressure on natural resources. The Circular Economy Action Plan indicates that the Commission will support the substitution and elimination of hazardous substances through research and innovation. It includes initiatives addressing the entire life cycle of products, including how products are designed, as well as ensuring that waste is prevented and that used resources are kept in the EU economy for as long as possible. It introduces legislative and non-legislative measures targeting areas where action at the EU level brings real added value.

The European legislative backdrop

The framework for regulating chemicals and materials in terms of risks to human health and the environment includes the REACH Regulation (2006, named for the Registration, Evaluation, Authorisation and restriction of Chemicals)²³, and the associated CLP Regulation, named for the Classification, Labelling and Packaging

²² [Circular Economy Act](#)

²³ [Regulation \(EC\) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals \(REACH\)](#)

of chemicals, which defines the main classes of hazards and associated labelling)²⁴. Specific REACH provisions for substances in nanoform entered into force in 2020. There are also a large number of sectoral standards and legislation addressing chemicals in products, or groups of products, as is the case for regulations on medical devices²⁵, plant protection products²⁶ and cosmetics²⁷ for example.

REACH is built around the responsibility of companies to identify ways to safely manage substances they manufacture or import, by generating adequate data on properties of chemical substances, their hazards, exposure in identified uses, and fate. These data are generated according to procedures and standards that must ensure high test requirements.

Under REACH, **safety data sheets** are currently required for substances and mixtures that may be hazardous or toxic. The sheets include information about properties, handling instructions, measures to control exposure and so forth. It will be important to ensure that they also apply to advanced materials, at the appropriate level of technological readiness, and that the European Chemicals Agency (ECHA) has the capacity to support the evaluations.

The properties of materials arise from both their chemical composition and their morphology, including features such as particle size, shape, surface structure and other physical characteristics. This relationship is particularly important for advanced materials, where variations in physical form, such as nano-objects or other nanoscale structures, can lead to distinct behaviour. As a result, regulatory chemical safety assessments need to account for both composition and morphological attributes. Recognising the importance of these form-dependent properties, the EU introduced dedicated REACH provisions for substances in nanoform, in force since 1 January 2020, to ensure their proper characterisation and safety evaluation.

In January 2023, the Commission adopted a transition pathway²⁸ to help the chemicals industry contribute to the green and digital transition. A new chemical industry action plan is also expected, with the aim of supporting the

²⁴ [Regulation \(EC\) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures](#)

²⁵ [Regulation \(EU\) 2017/745 of the European Parliament and of the Council of 5 April 2017 on Medical Devices](#)

²⁶ [Regulation \(EC\) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market](#)

²⁷ [Regulation \(EC\) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products](#)

²⁸ [Transition Pathway for the Chemical Industry](#)

competitiveness of the industry, while also ensuring sustainability, security and safety.

As a rule, products are subject to both general and topic-specific standards and legislation. The Ecodesign for Sustainable Products Regulation aims to increase the sustainability and circularity of products in the European market, with a new digital product passport designed to help track substances of concern in products along the value chain²⁹.

At higher levels of technological readiness, the **digital product passport** (DPP) is a key instrument for transparency under the EU Ecodesign for Sustainable Products Regulation²⁹. The intention is to make information on product composition, performance, sustainability, and end-of-life options available in a standardised, machine-readable format that can be used by actors all along the value chain, helping all actors make choices that are better informed.

Digital product passports will be rolled out to a growing group of products through secondary legislation. Early targets include priority product groups with high environmental impact, complex supply chains, or significant reliance on critical raw materials. Focus areas include batteries, electronics, construction products, textiles, and plastics. Advanced materials per se are not addressed as a standalone category, but will feature in the products, components, and systems in which they are deployed. This ensures that functional materials such as battery materials, polymers, coatings, nanomaterials, and biopolymers are captured where they generate real-world impacts, while avoiding disproportionate obligations at early research and innovation stages.

The passports are intended to put the principles of Safe and Sustainable by Design (SSbD) into practice, with information requirements that evolve in line with the level of technological maturity. The idea is to include metrics for life cycle analysis, indicators of material efficiency, and pathways for reuse, recycling, and recovery, encouraging the early integration of sustainability while reserving full compliance and certification obligations for higher readiness levels.

An additional advantage of digital product passports is their potential to encourage the recovery and more efficient use of critical raw materials. By providing reliable information on material composition, concentrations, and disassembly options, they support improved sorting, recycling, and recovery and reuse at end of life.

Beyond the EU market, digital product passports are expected to support global compliance and convergence. While legally applicable to products placed on the EU market, they will in practice also influence international supply chains, as non-

²⁹ [Regulation \(EU\) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products](#)

EU manufacturers exporting to Europe will need to provide equivalent information, driving alignment in data standards, traceability practices, and sustainability reporting. Closely aligning digital product passports with regulations on advanced materials could therefore pay global dividends over time.

Advanced materials policies around the world

Many international players have national strategies for advanced materials, often blending anticipatory coordination efforts, upstream governance and strategic intelligence (OECD, October 2025). A number of these strategies explicitly aim to increase strategic autonomy. Both China and the US now implement technological and strategic policies to gain or maintain an edge over their competitors, in part through continuous monitoring and assessment of their respective capabilities.

China's efforts to reach the forefront of technological development date back to 1956, when it first identified chokepoint technologies required for 'technology self-reliance'. In 2015, with the adoption of the State-driven roadmap Made in China 2025 (PRC State Council, 2015), it set itself the goal of leading global manufacturing by 2049, with new materials singled out as a key short-term priority. This long-term strategy is complemented by investments that continue for long periods of time. In April 2025, a European Chamber of Commerce report found that after ten years, this combination of industrial policy, large-scale financing, and subsidies worth hundreds of billions of dollars had enabled China to achieve several major breakthroughs, and in the area of new materials, to make considerable advances in the journey from import dependency towards technological leadership. Biomanufacturing is singled out as a growth industry in China's 15th Five-Year Plan (2026-2030) (CPC, 2025), and in November 2025, the Ministry of Industry and Information Technology published a list of 43 companies chosen to construct new biomanufacturing pilot and scale-up facilities. China is also expected to build a new materials big data centre by 2035 with a view to leveraging AI in materials research, with a particular focus on aerospace, marine engineering and ICT, while integrating advances in superconductors and biomimetic materials. Several Pilot-Scale Platforms are also being constructed to accelerate the commercialisation of lab research into industrial capacity.

Granular analysis of Chinese research policy is difficult, but it is known for example that like the US but in contrast to the EU, it has a systemic capacity to monitor technological capabilities and act on this information at a central level, helping bridge gaps between lab and market. An estimated 100 000 people work in China's system for technology monitoring and assessment.

In the **USA**, research and innovation policies are largely determined at the federal level, and as in China, public financing plays a major role in research. The Office

of Science and Technology Policy helps design and implement policies related to science and technology, with the explicit aim of safeguarding US leadership in these fields³⁰. The overall approach to technology leadership is based on common shared principles, with the creation of market value as the top priority.

Federal guidance comes through the National Science and Technology Council, which draws up strategic plans to improve government coordination, and give long-term guidance for Federal programs and activities in support of United States manufacturing competitiveness, including advanced manufacturing research and development. The current planning document – the National Strategy for Advanced Manufacturing – expires in 2026, and the Office of Science and Technology is gathering input for the next iteration. The focus includes a concerted effort to step up strategic autonomy, with stakeholders being asked to identify disruptive manufacturing technologies with the potential to eliminate reliance on foreign sources for critical minerals and materials.

This new focus prioritises new jobs and economic growth, with no mention of environmental sustainability or climate change in its goals. The request for input notes a need to accelerate research and development, dismantle regulatory barriers, and ensure that the US is the unrivalled world leader in advanced technologies.

Many US initiatives and institutes face an uncertain future, with funding freezes, grant cancellations and the reversal of previous executive orders. But the scale of investment in research and development remains high – the 2025 federal budget for research proposed by President Biden was for USD 202 billion, dwarfing combined State-level spending, which stood at some USD 3 billion on 2023 (The White House, 2024). Federal funding is channelled through various sources including the National Science Foundation, the Department of Energy, the Department of Commerce, and the Department of Defence.

The National Science Foundation is traditionally one of the main funding institutions for research. Its beneficiaries include the Directorate for Mathematical and Physical Sciences, which currently lists 1646 grants related to advanced materials worth some USD 1.6 billion, and the Division of Materials Research, which supports fundamental research, and gave out 306 grant awards in 2024, including 20 university centres for materials research and engineering, multiple laboratory facilities to probe the structure and behaviour of matter, efforts to expand the STEM workforce, and core research programmes devoted advanced materials research.

The Department of Commerce has a primarily economic and commercial interest in advanced materials, with a considerable proportion of funding channelled

³⁰ [Technology Monitoring and Assessment – Comparing EU, US and Chinese Approaches. European Commission Policy Brief, 2025](#)

through a programme called Manufacturing USA, whose most recent Strategic Plan was released in November 2024. It brings together Innovation Institutes which convene private sector companies, academic institutions and other stakeholders to pursue collaborative research and development, test applications, train workers, and reduce the risks associated with deploying new technologies.

At the Department of Energy, a dedicated office for Advanced Materials and Manufacturing Technologies is tasked with boosting regional and topic-based innovation ecosystems through its network of Manufacturing USA institutes, user facilities, and innovation hubs, collectively referred to as consortia. They use federal funding as a catalyst to bring stakeholders together to address process and technological challenges in specific technology focus areas. Their mission is to drive and inspire innovation that transforms materials, manufacturing, and workforce and advances America's energy economy. Most of the national laboratories that depend on the Department of Energy also have dedicated programmes for advanced materials and manufacturing.

DARPA, the Defence Advanced Research Projects Agency, invests in high-risk, high-reward projects and working with an ecosystem of universities, industry, and government partners to maintain the U.S. military's technological superiority. Over the past 60 years, it has played an important role in research leading to the creation of the GPS systems, stealth aircraft, and the internet. DARPA focuses on advanced materials in a variety of projects and has a dedicated program for Materials Science.

Japan, the world's third largest research community (after China and the US), is a significant funder of research into advanced materials through the national research budget, and the EU and Japan hold enhanced dialogues in this area³¹. Between them the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Economy and Trade, and national institutes conducting basic research have a combined budget of between EUR - 1 billion and EUR 2 billion for advanced materials. A new government strategy to enhance materials innovation capacity is now being drawn up by the Cabinet Office, with recommendations that include a greater focus on high-performance, high-value-added materials where Japan currently holds technical superiority, materials that are key to resource security and supply chain resilience through the circular economy, and innovative manufacturing technologies combining advanced material design, evaluation and analysis. Japan also invests heavily in Australia, to reduce its dependency on China for materials.

India is emerging as a key player in the global advanced materials market, driven by initiatives like Aatmanirbhar Bharat (self-reliance) and Digital India, with a focus

³¹ See https://ec.europa.eu/commission/presscorner/detail/en/ip_24_1781

on renewable energy, automotive, aerospace, electronics, and infrastructure. The Indian advanced materials market, valued at EUR 1.5 billion in 2024, is projected to reach over EUR 3 billion by 2035. Globally, India ranks among the top 10 markets, with a 3% share of the EUR 75.6 billion global market in 2024, trailing leaders like China, the US, and Japan. Government investments of EUR 9–13.5 billion since 2020, through programs like the National Infrastructure Pipeline and India Semiconductor Mission, support innovations in nanomaterials, composites, and energy storage materials. India's focus on sustainability, digital tools, and research and development (R&D) positions it for significant growth, with a projected global market share increase to 5% by 2035.

The materials research sector in the **Republic of Korea** is growing fast. In July 2019, Japan introduced export restrictions on key materials used in Korea, and in reply, the Republic massively stepped up R&D investment, expanding its list of strategic technologies, launching programmes to accelerate breakthrough R&D, and deploying large-scale policy loans and funds to support industry. It also strengthened coordination between ministries, industry, and academia to align research priorities with strategic industrial needs. In 2024, a National Advanced Material R&D Development Strategy set out a comprehensive roadmap with both short and long-term goals. The aim is with both short and long-term goals to develop 100 critical materials within five years to ensure resilience, alongside 100 future-oriented materials to underpin next-generation industries.

Implementation is reinforced through an Advanced Materials Technology Growth Committee, demand-driven R&D and commercialisation support, AI- and data-driven research platforms, and large-scale research infrastructure. The Republic's approach is highly targeted, security-driven, and commercialisation-oriented, and may offer the EU a useful model to build more effective procedures to achieve key ambitions.

The **United Kingdom** has excellent research and development strengths in advanced materials, and consistently ranks among the top ten countries for research published and cited on materials science. Some 630 000 people work in this sector in the UK, and since 2021, the 27 000 companies involved in materials innovations have secured more than £8 billion a year in private and public funding for innovation activity within the UK, with demand for materials-related jobs expected to double by 2035.

In June 2025, the UK government's Advanced Manufacturing sector plan set out a national approach to the advanced materials with government, academia and senior representatives from across the UK advanced materials community. It noted a fragmentation and lack of coordination in the sector, and the need for a more joined up national approach. The plan aims to build up stakeholder networks, with a special emphasis on a new Defence Materials Centre of Excellence. New testing

and verification capabilities will help innovators accelerate the discovery, design, deployment, and testing of new advanced materials, supported by AI and machine learning. The plan is intended to dovetail with a coming Circular Economy Strategy, which will consider the evidence for regulatory circular interventions across the economy. Funding is also foreseen for research, training, and more international partnerships in industry and academia.

Having identified poor data sharing as a major barrier in this area, the UK is also supporting data-centric open research, with the Henry Royce institute providing materials data indexing systems, research data management support, and training.

Box 1 European research on advanced materials

Three recent reports give a good overview of Europe's research strengths in the area of advanced materials. The [Advanced materials: Evidence review report. Munich: SAPEA](#) (SAPEA, 2026) highlights the cross-cutting strengths in the research landscape, underlining leadership in excellent research, research infrastructures, standards and regulation, indicates areas where EU basic research is strong, and shows where applications are particularly promising. Leadership in applied research projects can be found in a JRC analysis of EU patents (JRC, 2025), and insights into EU strengths in fundamental research can be extracted from the ERC report on projects funded by the European Research Council (ERC, 2026). A number of highlights emerge:

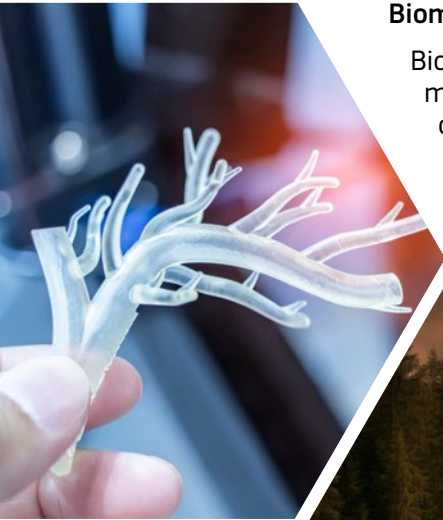
Biomaterials is an area where the EU has strong historical leadership. In 2001, the EU held more than 20% of worldwide patents on biomaterials, more than China and the US. Although this share has since decreased, the EU is still a strong actor in the field, holding a similar share of patents to the US. This strength is confirmed by the SAPEA report which characterises biomaterials as a promising sector for innovation in the EU. Among ERC projects, "Biopolymers and bio-derived polymers" is the second most funded sector (ERC), highlighting a strength in fundamental biomaterial research. Applications of biomaterials are very broad – examples include bio-compatible medical implants to replace traditional titanium and steel, soft robotics for medical technologies, and bio-polymers for tissue engineering (SAPEA, 2026). Metal-organic frameworks are also considered as a promising field in both the SAPEA and ERC reports. These frameworks could lead to very different applications, ranging from hydrogen storage to improved drug release.

Composites are another key area of strength, where the EU holds a higher share of patents than the US, China, Japan or South Korea. This strength is confirmed by the SAPEA report, highlighting that Europe has "excellent activities across several high-impact areas, such as composites" (SAPEA, 2026). Fundamental research in this field is also very well established. Polymer-matrix composite technologies are the most funded advanced materials research area by the ERC. Although still at the proof-of-concept stage, polymer-matrix composites could lead to a broad range of applications, from lightweight and more efficient materials for aircraft and the automotive sector to advances in the biomedical sector (Hsissou, R., et al.,

2021). Composites are also used extensively in the energy sector and wind turbine blades in particular (SAPEA, 2026).

The EU also has very strong leadership in ceramics research. According to the JRC report, the “glass and ceramics” category is one of the leading sectors of the EU advanced materials. The global share of patents in this field is comparable to those of the US and China. The SAPEA report also highlights functional ceramics (which includes piezoelectric, ferroelectric, and thermoelectric materials) as a key strength of the EU research landscape (SAPEA, 2026). Finally, the ERC highlights strong fundamental research in oxide ceramics, in particular perovskites which have applications in next-generation LED and photovoltaics.

Quantum, photonics and optoelectronic research, which includes compound semiconductors, 0D and 2D materials, is another area where fundamental research is strongly present in the EU (ERC). Compound semiconductors is the most funded sector by the ERC, followed closely by 0D (4th) and 2D materials (5th). This field is expected to have application in the sectors of electronics and energy. Recently, 2D materials such as MXenes have demonstrated promising properties that could lead to important applications in electronics and optics, energy storage, water desalination and in the biomedical sector (SAPEA, 2026). The patents study suggests however that this strength is not yet reflected in the industrial sector where the patent landscape of nanomaterials is mainly led by China, followed by the US and Korea (JRC, 2025).



Biomaterials for improved tissue regeneration

Biomaterials act as artificial or bio-derived extracellular matrices that support tissue repair and regeneration, often in combination with cells and bioactive molecules, actively guiding regeneration and unlocking safer, personalised therapies.



Composites for lightweight automotives

Polymer matrix composites are bringing advances to the automotive industry due to improved strength-to-weight ratio, as less weight means extended range. Highly recyclable, they are reducing waste and speeding the green transition.



Ceramics for efficient materials in aerospace

Ceramic matrix materials are making waves in the aerospace industry. They offer reduced weight, higher temperature capability, and more efficient cooling. The improvements to efficiency and fuel economy should lead to lower emissions.



Quantum materials for electronics

With their superconductivity and unique magnetic properties, quantum materials offer the possibility of a second computing revolution. They could open the way to a new generation of computing, communication and sensing, potentially before the end of this decade.

Figure 1: Examples of materials highlighted in the SAPEA ERR (SAPEA, 2026), the ERC report (ERC, 2026) and the JRC patent analysis (JRC, 2025), with potential examples of applications

Challenges and opportunities for European leadership in advanced materials

Advanced materials promise to **transform** technologies, industries and user experiences in application areas such as energy, health and electronics, construction and mobility. They are **intentionally engineered** (increasingly by combining multiple components), moving the scientific frontier to develop new materials that can deliver a superior performance (durability, efficiency, flexibility), while substituting toxic chemicals (biocompatibility), and reducing pollution, carbon footprint and reliance on (rare) raw materials (recyclability, minimization).

It therefore makes little sense to consider these materials solely in terms of their chemical composition, physical form and structure (their fundamental material class). Their purpose-driven development implies that the challenges and opportunities of these materials are embedded in their **functional** properties and behaviours (functional and phenomenological class), as well as their intended uses in specific applications and policy domains (OECD 2023a).

Despite Europe's strong scientific base and regulatory tradition, the pathway from materials discovery to safe, sustainable and competitive deployment is rife with structural roadblocks, which we attempt to address in the recommendations below.

A first cluster of challenges concerns **knowledge, metrics and data**. Existing standards and methodologies do not offer the kind of unambiguous guidance that helps users weigh up environmental, social, economic and circularity dimensions in a coherent manner, across full life cycles and complex value chains. This makes it difficult to prioritise materials that truly strengthen strategic autonomy, reduce dependencies and deliver societal value, while avoiding burden-shifting between stages or impact categories. Similarly, fragmented data that is difficult to access coupled with unclear rules about sharing and reuse undermine the reliability and comparability of evidence. These obstacles are addressed with recommendations about consensual metrics and data infrastructures in the Overarching Recommendation and R1.

A second cluster of obstacles arises from **value conflicts and complex governance**. Decisions involving SSbD are inherently multi-dimensional, with difficult trade-offs between performance, affordability and time-to-market, and stakeholders whose interests are not aligned and may not be compatible. Without clear processes, transparent criteria and robust decision support, there is a risk that SSbD remains either an aspirational label or a purely technocratic exercise that fails to deliver societal trust. In parallel, the perception of regulation as a brake on innovation can encourage opacity about risks, "green claims" that are not evidence-based, and the under-reporting of negative results.

These obstacles can be addressed with rules that are clear, predictable and rooted in science, and which form a solid base on which responsible and future-facing innovation can be built. The Overarching Recommendation and R2 respond to these challenges by

making Ethical, Legal, and Social Implications (ELSI) and Transparency, Accountability, Participation, Integrity, and Capacity (TAPIC) principles standard practice, with a view to strengthening stakeholder participation, and delivering standards and frameworks that guide both **the outcomes** to be pursued and **the manner** in which decisions are made.

Third, Europe faces structural barriers linked to **fragmentation of infrastructure, skills and funding**. Access to pilot lines, characterisation facilities, testbeds and certification support remains uneven across regions and sectors, with small and medium enterprises (SMEs) and start-ups most affected. Initiatives such as Open Innovation Test Beds and Technology Infrastructures are still underused, while skills shortages in materials informatics, regulatory science, data stewardship and AI-ready experimentation slow down the uptake of new approaches. At the funding level, programmes remain fragmented across national schemes, Horizon Europe pillars, and defence-related funds, with limited alignment around shared milestones and lab-to-fab pathways. These roadblocks are addressed in Recommendations R3 and R4.2–R4.5, which call for coordinated infrastructure, clearer skills pipelines, more coherent funding strategies and uniform monitoring mechanisms such as a Materials Impact Observatory.

Digitalisation and **AI** bring both opportunities and specific vulnerabilities. Self-driving labs, Digital Twins and circular-materials analytics are all extremely promising, but their arrival is being slowed by differing data formats, a lack of common data languages, and limited interoperability between models and databases. High costs, uneven access to digital infrastructure, and skills shortages are hindering widespread adoption. Without clear standards for validation, audit trails and “fitness-for-AI” labelling, there is also a risk that AI tools reinforce biases or unfounded predictions. Recommendations R1.1–R1.5 respond to these issues with proposals on data sharing, AI-assisted data hubs, common taxonomies, self-driving lab testbeds and shared Digital Twins under robust governance. Respecting Intellectual Property is essential to allow for innovation, and hence we recommended allowing time-restricted confidentiality and fast processing of exemption requests.

Lastly, the feasibility of any advanced materials strategy is shaped by **systemic** and **geopolitical constraints**. Dependencies on critical raw materials, volatile energy prices, and dual-use concerns at the interface of civil and defence applications complicate industrial planning and governance choices. Unless explicit attention is paid to strategic alliances, to secure access to green and affordable energy, and to structured links between civil and defence research, efforts to scale advanced materials may stall. The Overarching Recommendation and R3.4 and R4.1–R4.4 address these risks by aligning materials priorities with EU values and strategic autonomy objectives, strengthening international cooperation, and linking advanced materials policy to broader agendas on raw materials, energy and security.

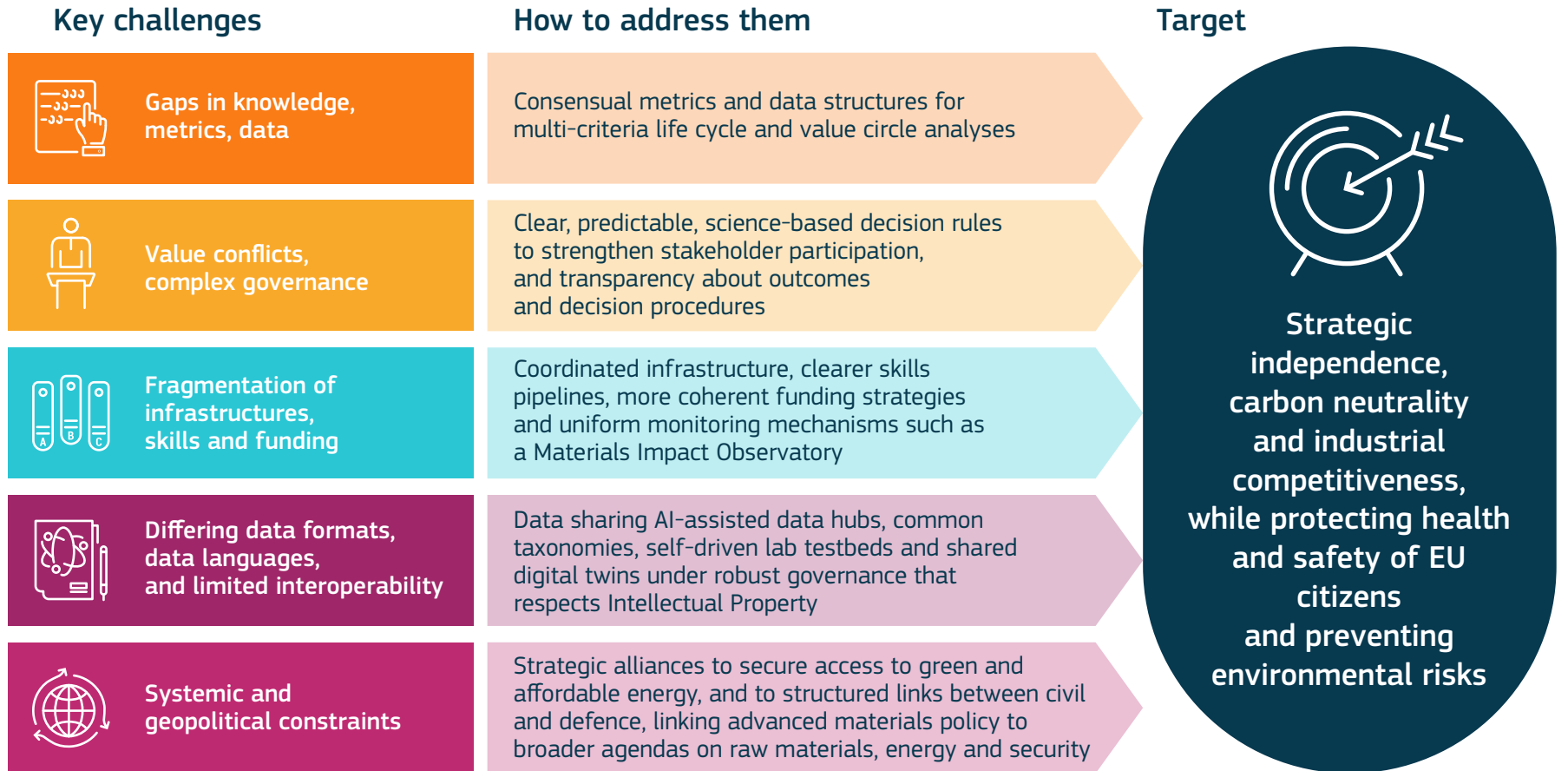


Figure 2: Summary of the overall vision underlying the recommendations, challenges identified and measures to tackle them

Taken together, these pitfalls and roadblocks clearly show that **a piecemeal approach will not suffice**. They underline the need for **ambitious action on advanced materials**. Turning Europe's scientific strengths into resilient, value-aligned industrial leadership will require a package of measures involving data and metrics, governance, infrastructure, digital tools, and training. Combining these measures in an **integrated approach** will deliver that change, while ensuring that Europe stays true to its values.

Overarching Recommendation

Ensure that policies for advanced materials prioritise EU values related to autonomy, safety and sustainability, and prosperity

Europe has demonstrated strengths in developing and adopting advanced materials (SAPEA, 2026). The EU policy frameworks that regulate chemicals, climate change mitigation and sustainability requirements are bolstering research excellence in many fields, and investments in excellent research are improving the quality and reliability of European databases and digital tools. The results facilitate the discovery of additional materials, delivering new materials to reduce energy consumption and carbon emissions, composites and ceramics that enhance the durability and recyclability of products, and bio-inspired and bio-degradable materials that improve user safety and sustainability.

These research strengths reflect the core values and interests of the European Union.

Our Union is built on values – on respect for human dignity, freedom, democracy, equality, the rule of law and respect for human rights. These values are reflected in the oath to ‘do no harm’ in the European Green Deal³². They become the legal requirement to ‘do no significant harm’ set out in the Regulations on sustainability-related disclosures³³ and the EU Taxonomy,³⁴ and they are reflected in programs like Horizon Europe, which are obliged to ensure that EU funding, policies, and economic activities do not undermine social objectives and key goals for climate, water, the circular economy and biodiversity.

EU strengths in advanced materials are being translated into applications in the fields of energy, health, electronics and mobility, construction, agriculture and environment, which have been identified as industrial priorities in advanced materials governance.

Reflecting on EU interests in the 2025 State of the Union address³⁵, President von der Leyen stressed the growing need to ensure Europe’s independence in multiple domains, from defence and security to technology and the energy that fuels the EU economy. She emphasised the advantages of a more circular economy, which would lower the demand for the imported materials we currently need for clean technologies.

³² [The European Green Deal](#)

³³ [Regulation 2019/2088 on Sustainability-related disclosures in the financial services sector](#)

³⁴ [Regulation - 2020/852 - EN - taxonomy regulation - EUR-Lex](#)

³⁵ [2025 State of the Union Address by President von der Leyen](#)

Our **overall recommendation therefore is to ensure that efforts to develop advanced materials are aligned with the core values and interests of EU citizens**. Advanced materials should open the way to EU strategic independence, carbon neutrality and industrial competitiveness, while protecting health and safety of EU citizens and preventing environmental risks.

To make this possible, a substantial collaborative effort will be required. We need decisive action to improve the reliability and accessibility of data, build consensus on relevant standards, ensure transparency in decision-making criteria, promote the effective (re)use of scarce raw materials and resources, and clarify responsibilities for uncertain outcomes.

The EU is uniquely placed to deliver this. But it requires mechanisms to align the interests of stakeholders, regions, and owners of intellectual property, long-term investments, and multi-stakeholder business strategies that contribute to Europe's future prosperity.

The sub-recommendations below lay out the key conditions that should inform an integrated EU strategy for advanced materials and help Europe work towards these goals. Recommendations R1 to R4 then set out actions that would turn these ambitions into real-world change.

Leverage the strategic benefits of safety, sustainability and circularity in advanced material features and applications through better metrics

Advanced materials have the potential to become a cornerstone of the EU's strategic autonomy, sustainability, and long-term prosperity, but their development and deployment raise complex questions in economic, social, technological, and health and safety spheres. In addressing those questions, the strategic benefits of mainstreaming safety, security, and circularity in the composition, properties, functionalities, and use of advanced materials must be made clear. This will be essential to maximise their societal value, and to ensure that innovation is aligned with Europe's values and its objectives for EU security, its economy and environment.

Research is therefore needed to deliver metrics that help quantify key criteria and specify timelines towards the realisation of safer, more sustainable, energy-efficient or circular applications. This research should also cover hypothetical options and long-term possibilities. These metrics should make it possible to systematically weigh and compare the likely benefits, uncertainties and risks of different materials, functions, and products across multiple dimensions along the life cycle (Guinée, J. B., et al., 2022) and at different Technology Readiness Levels as products are developed.

We therefore **recommend targeted research into these issues to inform policy design, and support responsible innovation in advanced materials**, to ensure the EU's strategic autonomy, sustainability, and long-term prosperity.

Strengthen EU resilience and autonomy and build social trust through tiered data sharing and strategic alliances

The successful uptake of new materials and products will depend on social acceptance and political support in Member States and regions, both of which are needed to secure long-term investments, build consumer trust, and ensure market access for advanced materials.

To predict and track the impact of advanced materials on strategic autonomy, timely, reliable, and transparent data are needed. By monitoring information about circularity, impacts on biodiversity, job quality, SME uptake, and time-to-market, such data would help ensure that change does not come at the expense of sustainability or social cohesion. It would also feed evaluative assessments and help keep policies effective.

Facilitating digital alliances between public and private actors located in the EU would enable the development of common approaches that support strategic autonomy, and strengthen resilience in the face of geopolitical uncertainties (Peijnenburg et al., 2021).

Options for sharing data internationally, with adequate safeguards, should also be explored. This would enable the pursuit of “open strategic autonomy”, and partnerships with like-minded countries, provided the appropriate controls are in place to manage exports and dual-use issues, with the necessary ethical oversight.

Integrate ethics, transparency, and sustainability by design to all stages of advanced materials research and innovation

Alignment with EU values implies an engagement with responsibility and sustainability across the full lifecycle of advanced materials innovation. In addition to focusing on requirements to prevent pollution and health hazards, and to lower carbon emissions, sustainability also includes a consideration of impacts on biodiversity, water, soil, toxicity, durability/reparability, extended producer responsibility, and high-value reuse³⁶.

The confidence and trust of investors, businesses and end users can be strengthened through the transparent and stringent testing of claims about safety,

³⁶ [SAM \(2024\). One Health governance in the European Union. Publications Office of the European Union.](#)

sustainability and circularity (Trump et al., 2023), and by integrating regulatory requirements into innovation processes (Schmutz, M., et al., 2020).

Current social value and business models prioritise economic gains over health risks and negative social and environmental outcomes. In practice, this means that little regard is often paid to safety and sustainability in product design and development. The EU addresses this problem with regulations ³⁷ that oblige many companies to consider such risks across their value chains. Many SMEs and research industry scale-ups are not bound by these obligations. However, they are still part of the value cycle, and should be stimulated to anticipate safety and sustainability issues at all stages of materials discovery and product development. Moreover, risks are not only contained in properties, functionalities or applications of materials, but are also associated with behaviour of users and operators (Van de Poel, I., & Robaey, Z. 2017). Hence, input from social sciences and humanities research will benefit the design of responsibility structures that incentivise safety issues (Van Gelder, P. et al., 2021).

We recommend adopting an iterative multi-stage funnel approach to the research and development pipeline as a means to embed societal values and long-term responsibility into innovation pathways (see Figure 3) (Bouchaut, B. et al., 2020). Stepwise guidelines recommending the consideration of ethical, legal and social issues should be applicable at all stages of materials discovery and product development. Attending to transparency, accountability, participation, integrity, and capacity (Greer, S. et al., 2019) in governance and decision making will facilitate public acceptance and market uptake. In addition, we recommend that any regulatory obligations should be carefully calibrated to technology readiness levels.

³⁷ [EU Directive 2022/2464 on Corporate Sustainability Reporting](#) and [EU Directive 2024/1760 on Corporate Sustainability Due Diligence](#)

Designing for safety and sustainability

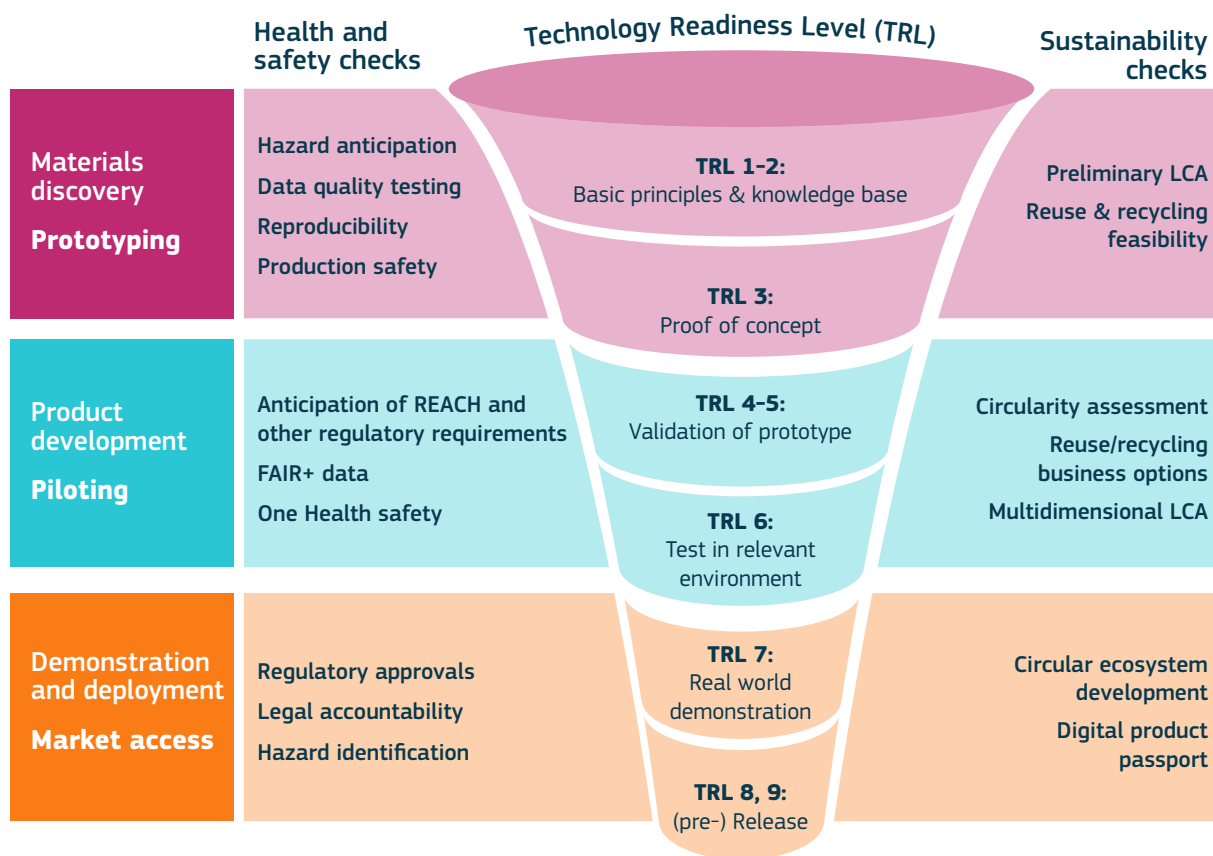


Figure 3: Summary of the strategy to ensure safety and sustainability in advanced materials innovation

Current strategies to classify advanced materials, and innovations in general, include the Technology Readiness Level (TRL) scale. The scale provides a widely used framework that describes the maturity of a technology, moving from early-stage fundamental research and proof of concept (TRL 1–3) through prototyping, testing and pre-commercial trials (TRL 4–6), to real world demonstrations and market deployment (TRL 7–9). In the context of advanced materials, Technology Readiness Levels capture the transition from materials discovery and proof-of-concept to integrated components and final products operating in real-world conditions. The concerns are different at every level. At low readiness levels, the focus is on understanding and documenting the intrinsic properties and potential hazards of materials. At the higher end of the scale, the focus shifts to the roll-out of the technologies, with implications for manufacturing, supply-chain dependencies and cumulative impacts on environment and health, depending on intended uses and sectors. This Opinion makes the case for a phased increase of measures towards full compliance before market release, anticipating final targets for safety, sustainability, and critical-raw-material considerations. This would ensure that requirements remain proportionate and feasible as technologies mature building up to full regulatory compliance before release, without stifling early-stage innovation or delaying responsible market uptake.

Engage stakeholders, develop transparent criteria and clarify priorities to support multi-criteria decision-making

Safe and Sustainable by Design cannot be achieved by the simple addition of new specifications to existing processes. Multi-criteria decision-making is required to navigate the broad range of risks and outcomes of concern that may be involved. Difficult trade-offs may be encountered between apparently incomparable outcomes that affect different stakeholder groups. There may also be value conflicts with no obvious optimal solution, such as safety vs. sustainability, or substance toxicity vs. energy efficiency (Soeteman-Hernandez et al., 2023; Bouchaut, B., et al., 2021; Schwirn, K., et al., 2025).

To ease the process, policies aimed at supporting multi-criteria decision-making should be guided by a concern for both the end goals of the policy, and the means of reaching those goals. This means paying particular concern to all groups affected by the decision-making process, to facilitate buy-in from stakeholders.

Our recommendation is to build an ecosystem of different actors representing the perspectives of a range of stakeholders, including industry, regulators, users, policy and makers. Each actor should be allowed to share the risks they face and the outcomes they desire, and be involved in the process of transparently evaluating and prioritising actions as part of the decision-making process. Decision scientists can help guide this process, and help build appropriate tools for decision support.

Progressive checks and balances should apply to different technology readiness levels, to ensure that product development and steps toward certification go hand in hand.

Incentivise public investment and market access for advanced materials innovation aligned with core EU values, interests, and priorities

For advanced materials to deliver their full range of potential benefits, mechanisms will be needed to increase their uptake. When coupled with predictable standards, **outcome-based procurement**, where buyers ensure that supplier deliverables are in line with strategic objectives, can be used to reinforce trust and legitimacy, enabling public and private buyers to prioritise sustainable and strategic materials, while supporting credible pathways from research to certified products.

Outcome-based green/innovation procurement can tie long-term funding to key performance standards that are fully aligned with EU values. Similarly, blended finance can be used to de-risk first-of-a-kind plants, and support responsible investment. Smart specialisation and widening instruments under schemes like Horizon Europe can be mobilised to distribute infrastructure and expertise more

evenly across the EU, avoiding geographic concentration and reinforcing cohesion by strengthening less-developed regions.

Above all, funding and procurement should prioritise proposals that demonstrably advance EU interests, priorities and values in the field of advanced materials by addressing environmental, social and economic dimensions across the full life cycle, embedding circularity and eco-design from the outset, and using Safe and Sustainable by Design as the default approach.

Recommendation 1

Support the creation of data spaces for Findable, Accessible, Interoperable, and Reusable data, digitalisation, AI and computational methods for accelerating safe-and-sustainable advanced materials research and commercialisation

Computational and data-driven methodologies are an essential element in the advanced materials landscape. They enable faster discovery, clearer traceability, and earlier risk screening of advanced materials, all of which can reinforce competitiveness and even shape standards around the globe (SAPEA, 2026). The numerical implementations of physical and chemical models that they bring provide explainable, physics-grounded predictions to guide discovery, experiment design, and synthesis. AI and Machine Learning models bring data-driven methods that explain experimental results or act as surrogates for computational models, accelerating screening, revealing links between structures and properties, and enabling rapid iteration from lab to pilots (see R3).

Digitalisation and AI also act as cross-sector enablers. Shared data standards, interoperable models, and AI-ready workflows can allow insights from one sector like batteries or catalysis to transfer rapidly to other sectors like coatings, composites, biomedical materials, creating spillovers that amplify impacts.

In short, integrating AI and computational methods into the advanced materials R&D pipeline is not only a scientific upgrade: it is an essential policy lever that will accelerate discovery, foster industrial competitiveness, and reinforce Europe's leadership in safe-and-sustainable advanced materials.

To realise this potential, Europe needs more transparency and easy access to reliable data and digital information about trade-offs. Clear knowledge about sustainability and safety issues, unresolved issues and research gaps will reduce costs for development and risk mitigation, enhance cross-fertilisation and streamline market uptake (Casseo et al., 2024). Creating relevant metrics here will facilitate governance and product approval cycles (Schwirn, K., et al., 2025) that explicitly consider the social and environmental aspects in addition to economic and industrial advantages as key criteria in promoting development, manufacturing, use and disposal/reuse of these materials.

Several roadblocks currently limit the uptake of digitalisation and AI in advanced materials research. Data and metadata are often inconsistent and cannot be

compared across materials and research fields. Inconsistent data curation, the absence of a shared terminology, and uneven Research Data Management practices weaken the interoperability of data and limit the potential of AI. In terms of rights and legislation, data can also have licensing or confidentiality constraints. Rights over Text and Data Mining, validation kits, and audit trails are inconsistent. Data about circularity, waste streams, and socio-economic descriptors are often scarce and inconsistent. Trust in advanced materials modelling research (including for Digital Twins and self-driving labs) is undermined by a lack of standards for uncertainty quantification, fragile calibration and replicability across sites, and a lack of standard APIs/protocols. More generally, the lack of digital and regulatory skills is slowing the uptake of digitalisation and AI, as Europe has a general shortage of data stewards, lab-automation engineers, and information technicians who are literate about Safe and Sustainable by Design. Lastly, the cost of computing power and the energy required can be prohibitive, for both simulations and the development of AI.

Many of these problems are already recognised at the EU level, including the importance of high-quality data spaces, and the need for more support to AI and computational and data-driven methodologies. The EU RAISE flagship initiative – the Resource for Artificial Intelligence Science in Europe – opened as a pilot phase in 2025. RAISE will be a virtual institute that pools and coordinates resources needed for AI in science, computational power, curated and integrated data, excellence and skills and funding. Support for federated data platforms was described in a staff working document from 2022³⁸, and is implemented through a data space support centre³⁹ and platforms like Simpl. The launch of a federated platform for high-performance computing (EuroHPC Federation Platform (EFP)) is foreseen for 2026.

The recommendations below build on these initiatives, highlighting areas that need new or additional support.

³⁸ [Staff working document on data spaces | Shaping Europe's digital future](#)

³⁹ See [About DSSC - About - Data Spaces Support Centre](#)

R 1.1 Strengthen Europe's advanced materials pipeline with findable, accessible, interoperable, and reusable (FAIR+) and AI-ready data and trusted federated data spaces with embedded safety and sustainability information

Data is at the core of materials science research for modelling, experimentation, risk analysis and certification (SAPEA, 2026). Access to reliable data is key for timely product development and enables industrialisation.

In order to make the most of data sharing, we recommend the implementation of measures to make data Findable, Accessible, Interoperable, and Reusable (FAIR), with safety and sustainability information included in the datasets (FAIR+). To create high-quality data for AI, avoid duplicated work, and speed up discovery, **the GCSA recommends making FAIR+ the default for all work related to advanced materials funded by the European Commission** with time-limited allowances for IP where justified. This should include data, metadata, code, and input files, which will be deposited with clear licenses and versioning, including negative or failed experiments.

Safe and **trusted European data spaces** are needed to make such data available, while also providing transparency about different types of outcomes and how these inform strategies for further materials development. Federating these trusted data spaces will provide Europe-wide scale capability by collecting and combining data from basic research labs with relevant findings from prototype developments, industrial innovation and applications. Such federation will enhance early-stage collaboration, regulatory preparedness and industrialisation. Continuous data and knowledge sharing between researchers, regulators, industry and other stakeholders also benefits innovation and regulatory preparedness. Targeted governance and access rights should be specified to provide assurances that data are (experimentally) verified, reliable and cannot be tampered with, and that access is guaranteed when needed (e.g., for regulation or value chain approval) while IP is protected and national security considerations are taken into account.

A tiered approach to data access could be implemented, like the 4-tier model below:

Tier 1 - Open global data: Non-sensitive, well-anonymised, publishable. Available worldwide under open licences.

Tier 2 - Controlled access (global): Requires registration, data use agreements, maybe ethics/security screening. Accessible to vetted users globally (research, industry) if they meet conditions.

Tier 3 - Restricted access (EU + like-minded partners): Data with strategic or security relevance, or export-control issues. Access limited to EU entities and, where agreed, like-minded countries with equivalent legal/ethical standards.

Tier 4 - Highly restricted/non-shared: Data that should stay with the originator (e.g. certain defence-related, trade-secret, or safety-critical information). Only aggregated insights may be shared.

While the tiered data structure and the TRL scale capture different dimensions of the innovation pathway, there is some natural correspondence in practice. Early-stage, low-TRL research typically produces non-sensitive, publishable data which, once IP considerations are addressed, can reside in Tier 1. As technologies progress through prototyping and piloting (TRL 3–6), datasets increasingly involve controlled materials, performance data, or context-specific risks; these are more likely to fall under Tier 2 or, where strategic or safety considerations arise, Tier 3. For technologies approaching deployment (TRL 7–9), data often become commercially confidential or safety-critical, requiring Tier 3 or Tier 4 treatment. Defence-related or otherwise highly sensitive information will always require restricted access, generally Tier 3 or Tier 4, regardless of TRL. In short, although the two systems do not align one-to-one, the sensitivity and governance needs of data tend to increase as technologies mature, and the Tier structure provides a practical framework for managing this progression.

To encourage organisations to publish and share FAIR+ data with the appropriate actors, data citation should be recognised and rewarded. One way to do this is to include data citation as a Key Performance Indicator (KPI) in publicly funded projects. Funding conditions should request transparency about multi-criteria decision analysis to ensure that choices improve whole-life performance and do not shift burdens across stages or impact categories. Additional funding could be prioritised for proposals that include digital tools and FAIR+ data linking properties and uses to end-of-life pathways so that reuse, repair and high-value recovery become standard practice.

Example KPIs to measure impact could include⁴⁰:

- Percentage of projects that deposit FAIR+ uncertainty data in trusted repositories
- Change in time needed to identify a candidate solution, compared with a 2026 baseline
- Compute energy used per candidate identified
- Number of cross-sector pilot projects using shared Digital Twins or testbeds

⁴⁰ [Turning FAIR into reality](#)

- Share of products that meet SSbD criteria at TRL 6–7 without needing redesign
- Extent of use of digital product passports (DPPs) or compliance with DPP requirements
- Including these KPIs in funding calls and project evaluations would create clear, practical incentives for better data sharing and more sustainable innovation

The EU should also work on updating all existing Safe and Sustainable by Design datasets to FAIR+ standards, by enhancing coordination among existing bodies (e.g. Joint Research Centre, the Partnership for the Assessment of Risks from Chemicals, EOSC Association, Future Materials Commons etc.).

Use AI to connect data bases and speed up the development of FAIR+ data

The large number of databases, combined with the lack of interoperability, make cross-fertilisation of research among sectors challenging.

We recommend setting up a federated AI-assisted European FAIR+ Data Hub to connect major materials databases through open application programming interfaces (APIs) (OPTIMADE-style), with fields for provenance, quality, and uncertainty, and digital profiles industry can use for qualification, and material data to facilitate recycling and/or reuse, especially of critical raw materials. In parallel, and to speed up safe substitution decisions and reduce late-stage redesign, the EU should encourage the use of AI to fill hazard and exposure gaps, and add circularity and socio-economic fields (e.g., recyclability, critical raw materials, cost) in FAIR+ data.

Back the development of common data languages

Interoperability of data is key to turn scattered datasets into a usable European resource. However, research fields and applications sectors often use different languages which make data sharing challenging. Agreeing on common language for data sharing is therefore key to promote cross-fertilisation of research in the advanced materials field.

We recommend support for common data taxonomies agreed at the EU level. EU teams should be funded to agree on shared schemas and vocabularies (including how to record uncertainty) so data from labs and simulations can be combined and compared across countries and sectors. Such common data taxonomies could be developed with the support of a consortium like the MaterialCommons4EU.

Looking forward, the EU should issue guidance for uncertainty reporting, reproducibility, and dataset “fitness-for-AI” labelling to promote the publication of AI-ready data. The EU should issue practical guidance on text and dataset assets

“fitness-for-AI” labelling to accelerate the creation of high-quality, machine-readable data for advanced materials.

Unlock the existing scientific literature for AI

A large quantity of existing data is effectively ‘locked’ inside older scientific literature and patents. This includes legacy journal articles, supplementary PDFs, theses, technical reports, and patents, often as unstructured text, scanned tables, or figures, and represents a significant source of unexploited data that could feed into current AI models. Research initiatives should be financed to extract this data, using text and data mining so they can be converted into AI-ready format with clear provenance, licensing status, and appropriate attribution.

These efforts should prioritise standardised ontologies and metadata (including processing history and test conditions), capture uncertainty and negative results where available, and create trusted, interoperable datasets that can be readily integrated into EU materials modelling, Digital Twins, and AI-for-materials pipelines.

R 1.2 Boost modelling and experimentation for advanced materials research and development

Trial-and-error remains a costly bottleneck in advanced materials discovery and scale-up. Stronger predictive capabilities, enabled by richer datasets, high-fidelity simulation, automated experimentation and AI can replace large parts of this cycle with targeted, evidence-based exploration, reducing time-to-candidate, material waste, and downstream safety and performance risks.

Building on Europe’s strengths in modelling the EU should sustain and modernise flagship simulation codes (e.g., VASP and Quantum ESPRESSO) and the surrounding software ecosystems (libraries, workflows, training, and user support) (SAPEA, 2026). In parallel, EU programmes should drive the systematic integration of safety, sustainability, and circularity indicators into modelling and automated synthesis workflows so that hazard, resource intensity, dependence on critical raw materials, recyclability, and end-of-life options are assessed alongside performance and cost well before manufacturing and scale-up.

EU materials software and compute workflows should remain scalable, accurate, interoperable, and energy-efficient, including optimisation for modern architectures and reporting of computational energy use where feasible, to ensure that digital acceleration supports Europe’s sustainability objectives.

R 1.3 Support self-driving labs

Self-driving labs can compress the cycle from ideas to validated material. China for example has gained particular leadership in this type of autonomous laboratories, where experimental platforms are automated and integrated with AI models, chemicals databases and management systems⁴¹. The EU should create self-driving lab testbeds with open pilot lines where AI plans experiments, robots run them, and results feed back into models – with SSbD and uncertainty handling built in. In order to bring smaller players into high-end facilities, we suggest funding programmes where SMEs and research institutes can plug into shared pilot lines or testbeds. Success should be measured with simple KPIs: shorter cycle time, lower energy per discovery, and a higher share of candidates passing Safe and Sustainable by Design checks as materials and products begin to approach market readiness.

R 1.4 Support Digital Twins

Digital Twins that emulate the behaviour of real-world systems should be supported as a shared European asset. Common Digital Twins speed testing, help avoid duplication, and facilitate alignment between industry and regulators. Open, application-driven Digital Twins accelerate materials qualification and scale-up, reduce duplication across R&D programmes, and align innovators, manufacturers and regulators from the outset. Such Digital Twins should span the advanced-materials lifecycle, from materials discovery and process development to product performance and end-of-life behaviour. A portfolio of reference twins should be co-developed with industry and standards organisations, and regulators for priority materials systems (e.g., batteries and solid electrolytes, recyclable composites, protective coatings/corrosion, catalysts, and semiconductor/photonic materials). This would require clear uncertainty quantifications, and published validation kits plus regulatory data packages so companies, in particular SMEs, can adopt them quickly.

R1.5 Promote the use of digitalisation and AI in tools and analytics across the whole value circle

AI can vastly speed up discovery, but expanding the predictive power of AI in circular-materials analytics can also improve forecasting, reduce dependencies, and increase circularity. AI-enabled approaches, combined with high-quality data from industry, recyclers, and waste operators, should be used to identify high-value

⁴¹ [Autonomous laboratories in China: an embodied intelligence-driven platform to accelerate chemical discovery - Digital Discovery \(RSC Publishing\)](#)

inputs in EU waste streams, improve sorting and pre-processing decisions, predict material properties and degradation, and accelerate AI-assisted design of advanced materials (e.g., inverse design of formulations and architectures that meet performance, cost, safety, and sustainability targets). These capabilities should explicitly prioritise design for sustainability: simpler material stacks, modular designs, reduced use of hard-to-separate additives, and choices that preserve recyclable quality and enable high-value reuse.

Because AI can also introduce environmental burdens, EU action should require proportionate, transparent accounting of the energy and carbon impacts of training and deploying large models (including large language models used for materials discovery, process optimisation, and compliance documentation). This includes reporting energy use where feasible, favouring compute-efficient methods (smaller or specialised models, fine-tuning over training from scratch, efficient inference), using low-carbon compute infrastructure, and aligning AI deployment with SSbD so that digital gains are not offset by avoidable computing emissions. Where large language models are used as decision-support (e.g., literature mining, synthesis planning, hazard and circularity screening, or regulatory and supply-chain documentation), they should be integrated with traceable data pipelines, uncertainty reporting, and human oversight to ensure scientific reliability and responsible adoption.

Recommendation 2

Design standards for advanced materials to support safety and sustainability at every level of technology development and facilitate market access

Advanced materials is an extremely complex field, and materials can be classified in various ways – according to chemical properties and formulation, functionality, and application. The chemical and formulation classification can range from living cells to quantum dots, while applications might include for example building materials, medical devices and electronics.

In view of the difficulties of covering all possible materials, functionalities and applications, the critical assessment of safety and sustainability needs to be integrated at different stages of the advanced materials pipeline in different ways. This can ensure that unforeseen innovations, material properties and safety challenges are also covered by adequate standards.

To maximise their pivotal potential, multi-dimensional life-cycle assessments should include risks and hazards that do not only pertain to health concerns (proportionality of exposure vs toxicity etc), but also an assessment and quantification of other risks and hazards such as ecological and social implications and foreseeable costs. Finding a way to quantify these is a challenge in its own right.

This requires also a reliable methodology for the **early-stage identification of potential safety and sustainability issues** and risk governance throughout the discovery and development phases will be essential (Peijnenburg, W., et al., 2021). Stepwise prevention-based risk governance is fundamentally different from the current approach, which focuses on retroactive risk mitigation (Hristozov, D., et al., 2023) and is often driven by commercial certification initiatives.

Progression from materials discovery to product design will be facilitated by the development of unambiguous protocols to anticipate specific risks or standards that are relevant to strategic decision making at each stage of development, and which indicate the compliance requirements that are appropriate to each technology readiness level. An approach like this can reduce risk and uncertainty for enterprises, while also reducing impacts that could be detrimental to public health and the environment.

Reliable stepwise characterisation of potential risks and benefits could allow for new forms of governance that match the dynamic and shifting features that

characterise advanced materials. This will facilitate rapid transfer from discovery to industrial uptake through regulatory preparedness (Schwirn, K. et al., 2025).

Europe has a core strength in developing new standards, and it needs to draw on that strength and on the recent experience of legislation surrounding nanomaterials in particular to develop the appropriate standards. As many safety and sustainability issues depend on end-products, sector and use, our recommendation is to follow the approach taken with nanomaterials, with amendments and additions that build on the existing chemicals acquis with sector-specific legislation.

To help the EU advance towards zero pollution, all standards in this area should be aligned with the principles set out in the framework that defines SSbD criteria for chemicals and materials.

Clear and transparent regulatory standards, combined with feedback on the process of deployment and use (e.g. by industry) and visible compliance monitoring, can help businesses mitigate any risks throughout product development stages, while helping build trust among users throughout the supply chain and value cycle and among the general public as regards the use of these materials.

The aim of these recommendations is to boost innovation in the EU while supporting protection of safety and sustainability, creating a system where high-quality data flows more freely, clear targets guide responsible development, and European-made advanced materials can thrive sustainably at the internal market and set a benchmark worldwide.

R 2.1 Develop a clear, shared vision of relevant legislation and guidance, via a process of continuous dialogue between researchers, industry, regulators and other stakeholders

To address advanced materials, EU regulators can either modify or build upon the existing chemical and product safety frameworks or create entirely new instruments. Each of these suggested regulatory approaches has strengths and weaknesses that must be considered before deciding in favour of one or the other (SAPEA, 2026).

In principle, the regulation of advanced materials can rely on and adapt existing regulatory frameworks and non-legislative measures (strategy documents, guidance, etc.). This could be, for instance, to amend existing chemical legislation such as REACH and the CLP (SAPEA, 2026).

At all stages of the process, from inception to ongoing collaboration, a continuous inclusive dialogue should be maintained between product developers, manufacturers, end users, civil society and regulators, following the good example

set by the Technology Council for Advanced Materials. The framework should be continuous, and should intensify as materials approach market readiness.

R 2.2 Define metrics and methods for advanced materials, appropriate to each technology readiness level, which address safety, environmental, social and economic dimensions

Standards and guidelines play a central role in ensuring both future competitiveness and the societal acceptance of advanced materials. These need to support all stages in the materials discovery and product development cycle, safeguarding safety and sustainability while also ensuring regulatory preparedness by equipping policymakers with the knowledge they require to base their recommendations in solid science, in line with SSbD principles.

Various obstacles currently hinder the development of such metrics, including absent or fragmented data on environmental impacts and on the safety of production and commercialisation, and lack of consensus on how to quantify broader indicators of public health and social impact. There is also an absence of harmonised testing methods, resulting in insufficient regulatory readiness (SAPEA, 2026). Moreover, advanced materials often display complex behaviours or allow for multiple uses and functions that make risk assessments challenging (SAPEA, 2026).

To address data gaps, mandatory registration should be introduced, as is currently the case for nanoform ingredients. The resulting databases could support hazard prevention, precaution, and proportionality. The process of collecting and registering such data would also facilitate more explicit consideration of trade-offs between multiple decision criteria, as well as including likely and unknown hazards and risks, and how these can be tested, measured and documented.

Existing legal and regulatory frameworks and testing frameworks will need to be adjusted, amended and expanded to take new materials into account, and new hazard categories may need to be defined. Integration with existing standards will also be required, via e.g. the European Committee for Standardisation (CEN), the Versailles Project on Advanced Materials and Standards (VAMAS), the OECD, and the International Organisation for Standardisation (ISO), as appropriate. This requires flexibility and dialogue, with feedback loops involving researchers, industry and other stakeholders.

For early stages of material or product developments, approaches like regulatory test beds or the “Early Awareness and Action System for Advance Materials” developed by the OECD may support assessments (OECD, 2023b).

As Europe moves towards a more circular economy, products containing advanced materials should factor in a concern for circularity from the outset. To facilitate the efficiency of recycling processes, standardised EU-wide symbols and terminology should be developed and implemented, including standardised input to digital product passports. In view of the push for greater European strategic autonomy, this will be particularly important for the recycling of products that contain rare elements, and for the development of closed loop recycling systems.

In cases where no viable alternatives exist or where urgent societal needs require rapid deployment, efforts should focus on identifying deviations from SSbD criteria, and specify how to progress towards safer, more sustainable substitutes. This might justify temporary regulatory exemptions, to allow for fast, transparent, and rigorously justified intermediate solutions, while ensuring continued progress toward safer, more sustainable substitutes.

We suggest that regulations be linked to the Technology Readiness Level of the product in question (See Figure 2):

Low TRLs (1–3) → qualitative screening, hazard anticipation, circularity potential

Mid TRLs (4–6) → comparative LCA, substitution analysis, CRM risk mapping

High TRLs (7–9) → hazard identification, certification readiness, compliance evidence

R 2.3 Utilise the full potential of digital product passports to integrate sustainability features and support the recovery of critical raw materials building up to meet progressive requirements

In 2024, the EU adopted new legislation on digital product passports (DPP). The intention is to increase transparency across product value chains by making essential information about the origin, composition and disposal recommendations for the product in question easily available. The DPP is intended to eventually extend to most products placed on the EU market. It was developed in line with open data principles, with an emphasis on transparency and accessibility, as part of the EU Regulation on Ecodesign⁴².

This new legislation presents an important opportunity for the sustainability and future traceability of advanced materials. Our recommendation is that as a matter of priority, passports should systematically flag any critical raw materials contained in products, with a view to facilitating traceability, disassembly, recovery, reuse and

⁴² [Regulation \(EU\) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products](#)

efficient recycling. The EU regularly updates a list of raw materials considered to be critical⁴³.

The functionalities of DPPs could also be expanded to include clear sustainability indicators, noting in particular the presence of critical raw materials or materials that are not currently recyclable, to increase public awareness, allow for informed choices, and for the sharing of responsibilities. Such data will accumulate as the product progresses through the TRLs.

The Horizon Europe-funded project DigiPass CSA aims to develop a digital materials & product passport, which would include circularity and sustainability data, and could serve this purpose⁴⁴.

It is realistic to expect that industry will initially experience the DPP as burdensome, particularly due to increased data requirements, the administrative efforts involved, and sensitivities around intellectual property and commercial confidentiality. These concerns should be acknowledged. However, they must be balanced against the long-term benefits of regulatory clarity, improved access to secondary raw materials, reduced supply-chain risk, and more predictable market access for sustainable products. By embedding requirements into a shared digital infrastructure rather than relying on fragmented reporting obligations, the DPP ultimately supports efficiency and competitiveness. As far as possible, the DPP should already align with and support any further regulations on advanced materials.

R 2.4 Ensure support for databases and mechanisms for the sharing of information relevant to certification and regulation

The EU is making a significant effort to develop a robust data ecosystem in Europe through new legislation and infrastructure. Recent measures include the European Open Science Cloud (EOSC)⁴⁵, the Common European Data Space for Research and Innovation, and other Common European Data Spaces such as the European Health Data Space⁴⁶. Legislative initiatives include the Open Data Directive, the Data Governance Act, the Data Act and the forthcoming Data Union Strategy. The Materials Commons is another case in point.

⁴³ See https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

⁴⁴ See <https://ms.hereon.de/digipass/>

⁴⁵ See https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/our-digital-future/open-science/european-open-science-cloud-eosc_en

⁴⁶ See https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space-regulation-ehds_en

Various obstacles need to be overcome to facilitate the collection, registration and sharing of information for certification and regulation. This includes the fragmentation of research infrastructures, poor interoperability, data silos and privacy concerns addressed in Recommendation 1.

The early sharing of data, coupled with an approach built around SSbD, will also support regulatory acceleration. As noted above, mandatory registration in a manner similar to the one used for nanoform ingredients will help build databases with a focus on hazard prevention, precaution and proportionality, and feed discussions on trade-offs by including multiple types of likely and unknown hazards including social or ecological costs and risks, and how these can be anticipated and possibly tested, measured and documented.

EU support in these areas will be essential to ensure the systematic, accelerated access to information needed for certification and regulation, to boost the transition from research to deployment.

R 2.5 Develop a federated mechanism for testing and certification at EU level

While Europe possesses many world-class research facilities like CERN, EMBL, JRC, and ESRF, a lack of dedicated platforms for rapid testing and certification is causing the EU to lag behind international competitors. Access to centres for testing and certification is currently a problem for many EU businesses, and large parts of the Union have limited access to centres of this nature. With biotechnologies for instance, there is a bottleneck slowing the progress from laboratory to manufacture on an industrial scale. Certification processes are also slow, in part because advanced materials need to be incorporated into current systems, which often involves codesigning suitable procedures.

Learning factories and innovation sandboxes have the potential to significantly improve industrial technology, allowing businesses to test advanced manufacturing technologies and procedures in low-risk, enclosed settings that replicate real-world production conditions.

Sandboxes facilitate rapid development and industry collaboration. Academia, industry, and policymakers can test the upscaling potential of new materials under realistic conditions through shared infrastructure and experiments, while also allowing internal capacities to be built if needed. Tools such as Digital Twins, simulations and AI enable prototyping at pilot scale, and could also help accelerate certification and market entry.

Strengthening and expanding existing mechanisms for testing and experimentation open to all would lift the overall level of European competitiveness. Development

and adoption of an EU-wide specialised mechanism for certification of advanced materials, possibly associated to a mechanism for testing and experimentation, would speed access to markets. The early involvement of downstream regulators streamlines market adoption and certification. Involving researchers, industry and regulators in prototyping ensures that performance requirements are met from the start.

Recommendation 3

Strengthen ecosystems that effectively develop, coordinate and support initiatives to accelerate R&D uptake by the market

Advanced materials will only deliver on Europe’s strategic autonomy, leadership and sustainability ambitions if excellence in discovery is matched by excellence in manufacturing and deployment. Europe already combines outstanding research, world-class infrastructures for characterisation and pilot testing, and a dense ecosystem of innovation hubs, public-private partnerships and EU-level initiatives in materials and manufacturing (SAPEA, 2026), but despite these advances, one of the biggest obstacles to materials innovation remains scalability. For Europe to genuinely lead in the field of advanced materials, it is not enough to demonstrate promising material in the laboratory. What matters is the ability to produce it reliably, affordably and in large quantities, within sustainable and circular production systems and with capital and policy conditions that make scale-up investable in Europe.

For this to happen, financing gaps in both capital expenditure and operating expenditure that are hindering the scale-up process must be addressed. The solution we propose is a mix of blended finance, guarantees and targeted tax incentives (like accelerated depreciation/investment credits for pilot lines and first-of-a-kind plants) – and the alignment of these instruments with emerging “Made in Europe/Buy European” objectives for critical goods content, so that early demand helps anchor manufacturing capacity in the Union⁴⁷.

Bridging this “lab-to-fab” gap requires simultaneous innovation in materials, processes, and manufacturing systems, supported by shared pilot and technology infrastructures, learning factories and sandbox environments that allow realistic low-risk experimentation and scale-up. As noted above, open testbeds and learning factories can shorten the path from laboratories to certified products, especially when they are combined with a process of risk quantification that requires progressive action as development moves toward implementation.

Business-oriented de-risk mechanisms that boost the commercialisation of advanced material technologies and reduce the cost of capital at scale-up must be made more widely available (including, for example, bankable qualification

⁴⁷ https://single-market-economy.ec.europa.eu/publications/industrial-accelerator-act_en

evidence and predictable offtake). Additional research on innovation management, decision support, ethics and value judgments can help clarify and resolve the trade-offs and decision dilemmas that emerge when performance goals pull in different directions.

This recommendation therefore focuses on cutting time-to-market for safe and sustainable advanced materials. This can be achieved by coordinating infrastructures, partnerships, regulatory preparedness and demand-side instruments, so that Europe's scientific strengths are translated into competitive, resilient industrial leadership capacity.

The need for change is very real. Many innovations still stall at early stages because companies lack access to equipment, certification-ready processes and bridges between research and manufacturing. SMEs and start-ups in particular face prohibitive capital and operating costs to test or pilot new materials, duplication risks and fragmented access conditions across regions. This recommendation addresses those issues by suggesting subsidised access or standardised access rules for SMEs. SME participation can be further strengthened by lowering entry barriers through sandboxes, vouchers, shared testbeds and fair licensing models, enabling faster scale-up and wider diffusion of innovation across regions.

The current multiplicity of finance initiatives and partnerships further complicates the picture. This is why this recommendation focuses on leveraging EU–industry partnerships to consolidate investments, align them with “lab-to-fab”⁴⁸ milestones, and encourage inflows of private capital.

Europe also lacks strong demand-side pull mechanisms comparable to the “first-buyer” role of defence procurement in the US and China, limiting early markets for safe and sustainable materials. Hence, this recommendation sketches some elements of a solution here, such as harnessing public procurement and other demand-side initiatives to validate and de-risk novel materials in real applications. To be effective, these instruments should also help standardise expectations on performance criteria and provide clear, predictable regulatory signals for innovators and investors – and defence should be treated as a strategic lead market for dual-use materials, accelerating qualification while strengthening industrial resilience.

Lastly, Europe badly needs stronger feedback loops between researchers, manufacturing innovators, regulators and end users. This would enable lessons from scale-up, business-case viability and societal concerns to filter through to research agendas and investment priorities (SAPEA, 2026). Structured, continuous feedback mechanisms across these communities would help ensure that advanced materials R&D is steered from the outset by realistic manufacturing,

⁴⁸ [Communication on Advanced Materials for Industrial leadership](#)

market and regulatory constraints, helping Europe’s innovation ecosystem to move from isolated successes to a systematic “fast track from lab to fab”. Embedding decision-support approaches (including ethics and value-judgment frameworks) into these feedback loops can make trade-offs explicit and actionable, improving both societal legitimacy and investment readiness.

R 3.1 Map the ecosystem of academic and industry stakeholders to strengthen shared experimentation, and create a Technology Infrastructures Catalogue with a single access point

Materials innovations in Europe often stall in the “valley of death” – the gap that separates laboratory proof-of-concept from full industrial deployment. During this crucial stage, companies need access to semi-industrial pilot lines, advanced characterisation, certification-ready processes and regulatory guidance, but cannot yet justify full-scale industrial investments. Technology Infrastructures –facilities, equipment, capabilities and resources required to develop, test, upscale and validate technology, including Open Innovation Test Beds – are designed to de-risk this transition⁴⁹. They lower the cost and risk of testing new production routes, support compliance with safety and sustainability requirements, and shorten time-to-market, which is particularly critical for SMEs and start-ups that cannot build their own pilot plants.

The EU has invested in a first generation of Open Innovation Test Beds and related projects since 2019, bringing access to pilot lines, characterisation and modelling services. Evidence from both the SAPEA review and EU studies, however, indicates that these infrastructures are not yet fully utilised at EU scale. Awareness among SMEs is limited, access conditions and IP rules can be complex or opaque, and the landscape remains fragmented across regions, sectors and funding schemes, leading to duplication risks and uneven terms of access.

To unlock their full potential, the EU needs to expand and consolidate initiatives into a pan-European network of shared testing, piloting and upscaling hubs, tightly linked to research infrastructures. The SAPEA review stresses the importance of connecting ESFRI Research Infrastructures with the emerging Technology Infrastructures so that materials characterisation, bioprocess scale-up and advanced manufacturing capabilities form integrated, distributed ecosystems for advanced materials development and production.

Policy options in the SAPEA review further highlight the role of local “innovation spaces”, learning factories and sandbox environments where companies can

⁴⁹ [European Commission: Open innovation test beds for advanced materials – Examples and lessons learnt from one type of technology infrastructure, Publications Office of the European Union, 2023.](#)

experiment with new materials and processes under semi-realistic conditions, supported by modular production layouts, Digital Twins and scalable system design. In practice this means co-locating modular pilot lines, high-end metrology, digital tools and regulatory coaching, and using blended funding models to ensure long-term operation, while tailoring access rules and pricing specifically to SMEs. A dedicated multiannual funding stream should be created to operate and upgrade an EU Advanced Materials Testing & Qualification Platform, connecting Open Innovation Test Beds and pilot lines with metrology, certification bodies and support for Life Cycle Analysis and Safe and Sustainable by Design approaches.

A central pillar of this recommendation is mapping the full ecosystem of research and technology infrastructures for advanced materials, and turning this mapping into a living Technology Infrastructures Catalogue with a single digital access point. The Commission has launched a dedicated study (2025–2026) to inventory advanced materials research and technology infrastructure service providers, analyse gaps, overlaps and access conditions, and examine synergies with test beds, European Digital Innovation Hubs, testing and experimentation facilities and regulatory sandboxes; its explicit objective is to support the creation of a European single-entry catalogue for advanced materials-related Technology Infrastructures⁵⁰. This work should be extended and deepened, so that the resulting Catalogue not only lists facilities, but also classifies them by Technology Readiness Level, sector, materials class, and services available. Such inventories lower search costs, clarify which services are readily available, and generally improve user uptake.

Lastly, coordination at the EU level would help avoid infrastructure redundancy, facilitate coherent access, and ensure that safety and sustainability considerations are firmly embedded in the process.

The resulting EU-wide, well-mapped and digitally accessible network of Technology Infrastructures and Open Innovation Test Beds would help turn “lab-ready” advanced materials into scalable, investable and certifiable industrial solutions, particularly for SMEs that would otherwise be excluded.

R 3.2 Accelerate market demand by developing public procurement in key sectors of application

In the United States and China, public procurement often acts as the first large, risk-tolerant buyer of emerging technologies, especially in the defence sector (SAPEA, 2026). This creates assured lead markets for new materials and components, from semiconductors and advanced composites to sensors and

⁵⁰ [Implementation of the Actions on Advanced Materials](#)

protective systems and accelerates their scale-up into civilian sectors. Recent US policy explicitly frames defence acquisition reform as a tool to “spur innovation in the defence industrial base” and to speed up the adoption of new technologies in critical systems⁵¹. Europe, by contrast, lacks comparable large-scale “first buyer” mechanisms, slowing the industrial uptake of advanced materials despite strong research performance and a robust regulatory framework. In view of its heightened security needs, Europe should explicitly treat defence and dual-use procurement as a primary accelerator of the lab-to-fab cycle, rather than a secondary domain of application.

Developing public procurements in key sectors of application would address a structural gap that is identified in both the SAPEA review and in the Commission Communication on Advanced Materials. As noted in the Communication, advanced materials are indispensable for EU competitiveness and strategic autonomy in several key sectors, and policy initiatives must create a “fast-track from lab to fab” while “fostering the production and use of advanced materials”, not only their discovery.

EU law already provides a solid legal basis for this process. Directive 2014/24/EU requires contracts to be awarded not only on the basis of the most economically advantageous tender, thereby allowing contracting authorities to move beyond lowest price and to integrate quality, sustainability and innovation criteria into award decisions, opening the way to outcome-based procurement⁵². Guidance on innovation procurement from the European Commission further clarifies how public buyers can structure procedures (including competitive dialogues and innovation partnerships) to purchase solutions that are not yet widely available on the market, while managing risks and safeguarding competition.

Pre-Commercial Procurement and Public Procurement of Innovative Solutions are explicitly designed to let public authorities co-finance R&D, test prototypes and purchase first commercial batches of innovative technologies, de-risking scale-up and anchoring early manufacturing in Europe⁵³. Where compatible with EU rules and security constraints, tender design can also reinforce “Made in Europe” objectives for critical goods by linking evaluation/eligibility to EU-based qualification and supply-chain resilience.

The EU already pilots collaborative procurement models that can be scaled and adapted to advanced materials. The Big Buyers and Big Buyers Working Together initiatives bring together large public purchasers (cities, regions, utilities and national agencies) to jointly define needs, aggregate demand and run strategic

⁵¹ See for instance <https://www.businessofgovernment.org/blog/accelerating-technology-acquisition-within-us-department-defense?>

⁵² <http://data.europa.eu/eli/dir/2014/24/2024-01-01>

⁵³ [Pre-Commercial Procurement - Research and innovation - European Commission](#)

procurements for innovative and sustainable solutions⁵⁴. For advanced materials, such buyer groups could, for example, coordinate tenders for zero-emission bus fleets using next-generation lightweight composites and battery materials, or for hospitals seeking biocompatible implants and antimicrobial surfaces. By pooling demand, these consortia create procurement volumes that are comparable to those seen in the US defence sector and reduce the risk for suppliers investing in new production lines. Defence buyer groups and joint procurement should be added explicitly, focusing on dual-use materials qualification, rapid prototyping, and resilient EU-based supply.

The pre-procurement phase is crucial for ensuring that advanced materials are effectively considered as solutions. Systematic use of prior information notices and open market consultations allows public buyers to scan the market, engage with SMEs, and understand which advanced materials are compliant with Safe and Sustainable by Design and could realistically meet performance and regulatory requirements. At the same time, this dialogue helps innovators understand public needs in sectors like energy transformation, health, or defence, which are extensively discussed in the SAPEA review as key application domains.

Critically, designing tenders around ‘most economically advantageous’ criteria and EU guidelines on Green Public Procurement would ensure that cost is *not* the sole driver of award decisions. Incorporating life-cycle costing, carbon footprint, reparability, recyclability and exposure profiles of materials into award criteria directly rewards advanced materials that deliver superior long-term performance and lower environmental and health risks. This could be framed through explicit criteria for re-use, repair, refurbishing and recycling of advanced materials, alongside criteria for performance and safety in line with Safe and Sustainable by Design.

Targeted capacity-building would help make this shift operational. The Commission’s innovation procurement guidance and various EU-funded projects already underline the importance of training procurement officers in risk management, life-cycle assessment and innovation-friendly procedures. Building on these efforts with dedicated training modules on advanced materials would equip both procurers and suppliers to structure high-quality, innovation-oriented tenders. This would also support the broader ecosystem of innovation hubs, pilot lines and public–private partnerships, ensuring that results from EU-funded R&I can rapidly find their first markets through public buyers.

Developing public procurement in key sectors of application like the energy transition, health and defence would help transform existing EU legal tools and pilot programmes into a coherent demand-side pillar of the advanced materials strategy.

⁵⁴ <https://eurocities.eu/projects/big-buyers-initiative/>

It would leverage Europe’s strong regulatory and sustainability credentials to create home markets for SSbD-compliant advanced materials, reduce scale-up risks for innovators, and support strategic autonomy by anchoring production and high-value jobs within the Union with defence and civil security as explicit lead markets for early adoption and EU-based industrial capacity.

R 3.3 Leverage public-private partnerships to reduce fragmentation, redundancy and time-to-market

Fragmentation, duplicated investments and weak feedback loops between research, infrastructure and markets are core weaknesses of the current European advanced materials landscape⁵⁵. Public-private partnerships (PPPs) can help address these challenges with their potential to align strategic agendas, pool public and private funding, and provide a stable framework for long-term collaboration in advanced materials.

Horizon Europe’s European Partnerships are explicitly designed to avoid duplication of investments and reduce fragmentation of the research and innovation landscape by bringing public and private partners under a shared, long-term agenda. The IAM4EU partnership, implemented via IAM-I as a non-profit association of industry and research organisations and other research-related organisations⁵⁶, is being set up precisely to co-create and implement a Strategic Research and Innovation Agenda for advanced materials, with joint investments by the Commission and industry. Work programmes should also include explicit “capital-readiness” milestones (qualification evidence, offtake pathways, bankable business cases) and incentives to keep scale-up and production in Europe for critical goods. IAM-I published a position paper⁵⁷ on the Advanced Materials Act, proposing that it should be first and foremost an instrument to accelerate Europe’s advanced materials pipeline and shape the market from early research to large-scale deployment.

This mirrors successful blueprints in other sectors such as the Circular Bio-based Europe Joint Undertaking (CBE JU)⁵⁸, a EUR 2 billion partnership between the EU and the Bio-based Industries Consortium which coordinates calls, portfolios and impact monitoring to de-risk industrial investments and support first-of-a-kind plants in bio-based value chains. Joint Undertakings in this form demonstrate that public-

⁵⁵ [Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Advanced Materials for industrial leadership](#)

⁵⁶ [IAM-I | The Innovative Advanced Materials Initiative](#)

⁵⁷ [Position-Paper-IAM-I-Advanced-Materials-Act.pdf](#)

⁵⁸ [Circular Bio-based Europe Joint Undertaking \(CBE JU\)](#)

private partnerships can systematically translate scattered R&I projects into deployable platforms at scale and along whole value chains.

Aligning the work programmes of public-private partnerships and calls with the requirements for research and technology infrastructures mentioned in R 3.1 would ensure that the resulting investments directly drive technologies from lab to factory. PPPs should also be enabled to co-fund the multiannual operation of testing/qualification platforms, where market revenues alone cannot sustain capacity.

To further reduce time-to-market, public-private partnerships workplans should systematically incorporate innovation procurement, especially pre-commercial procurement and procurement of innovative solutions. Noting that the former is still underused in Europe, the European Commission is reinforcing the policy framework and funding under Horizon Europe.

Setting up a requirement for public-private partnerships to support a minimum number of pre-commercial procurement pilots would help ensure that such methods become an integral part of the development process, accelerating the deployment and widespread adoption of advanced materials technologies across Europe.

R 3.4 Foster circular economies and industrial symbiosis to accelerate material deployment and optimise resource efficiency

Accelerating the deployment of advanced materials while reducing Europe's dependency on primary raw materials requires a shift from linear "take-make-waste" models towards circular economy approaches and industrial symbiosis (SAPEA, 2026, chapter 2). Industrial symbiosis is an enabler here, keeping materials in productive use for longer and reducing reliance on primary raw materials (SAPEA, 2026, chapter 2). An EU review of 28 industrial symbiosis projects across 14 sectors confirms both environmental and economic gains and proposes a "Symbiosis Readiness Level" (SRL) framework, analogous to Technology Readiness Levels⁵⁹.

New business models such as material leasing and post-use recovery (often grouped as Product-as-a-Service) encourage producers to retain ownership of high-value materials, lowering lifecycle costs and mitigating critical raw material risks (SAPEA, 2026). In practice, leasing schemes for batteries, high-performance components or specialised advanced materials can be linked to contractual take-back obligations, refurbishment and high-value recycling, embedding circularity

⁵⁹ [Study and portfolio review of the projects on industrial symbiosis in DG Research and Innovation](#)

into core business incentives rather than treating it as a voluntary add-on. Targeted incentives (such as tax credits, green public procurement criteria and State-aid-compatible support) can further encourage re-use of materials and long-lived product–service relationships.

The EU could speed the adoption of such practices by increasing support for symbiosis platforms, where digital matchmaking tools identify cross-sector flows of materials, energy and water, and by leveraging support for DPP pilots for disassembly and high-value recycling and reuse of advanced materials.

As indicated above, public-private partnerships such as IAM4EU and sectoral Joint Undertakings offer a powerful vehicle to scale successful circular pilots into mainstream industrial applications. The Commission’s portfolio review on industrial symbiosis documents multiple EU-funded demonstrators across steel, chemicals, cement and other sectors. The next step would be to use public-private partnerships to replicate and adapt these models along advanced materials value chains. This includes integrating circularity and symbiosis into partnership work programmes, linking funding to the use of DPPs, open data and symbiosis platforms, and using SRL as KPIs alongside TRL and Commercialisation Readiness Levels (CRL).

Environmental Product Declarations (EPDs) provide independently verified, life-cycle-based information on product environmental performance, especially in construction under EN 15804⁶⁰. The Commission’s environmental footprint methods promote harmonised, LCA-based approaches that can also help substantiate environmental claims and combat greenwashing⁶¹.

Fostering circular economies and industrial symbiosis will act as a direct accelerator of advanced material deployment. It reduces dependence on primary raw materials, opens new business models (leasing, re-use, symbiosis), and creates a context where new materials can be tested, recovered and re-used at high value. By coupling circular industrial ecosystems with digital product passports, open sustainability data, AI-enabled optimisation and robust Environmental Product Declarations, the EU can speed up market uptake of sustainable advanced materials and consolidate its global leadership in resource-efficient, transparent and trustworthy material innovation.

⁶⁰ [Environmental Product Declaration](#)

⁶¹ [PEF Method - Green Forum - European Commission](#)

R 3.5 Create a Materials Impact Observatory to monitor production, exposure risks and obstacles between research and deployment

Creating a European Materials Impact Observatory is essential to close the current evidence gap between advanced-material R&I, governance for risk and Safe and Sustainable by Design, and market deployment (SAPEA, 2026). The SAPEA Evidence Review Report stresses that information about current and future production volumes, applications, numbers of units sold, concentrations and duration of use is a prerequisite for realistic human and environmental exposure assessment and thus for risk assessment of advanced materials. Despite that need, EU policy still lacks a coherent, cross-cutting system to evaluate material deployment and investment cycles across all technology readiness levels, and to feed this information back into regulation and funding priorities. A dedicated Materials Impact Observatory would fill this gap by systematically tracking how advanced materials move from lab to market, where they are used, in what quantities, and which barriers slow their uptake including financing/qualification bottlenecks that raise the cost of capital at scale-up.

The Observatory should call for traceable registries or reporting mechanisms for advanced materials entering the market, linking these data with exposure models and life-cycle analyses and embedding post-market surveillance and feedback loops into criteria for Safe and Sustainable by Design. This monitoring would provide the Commission with quantitative data to link material properties and uses to exposure pathways and inform SSbD assessments, risk management, end-of-life strategies and waste policy alignment, while enabling prioritisation, classification updates and the refinement of SSbD criteria across material categories. A Materials Impact Observatory would provide an integrated structure, offering a continuous, EU-wide evidence base for both innovation and precaution.

Existing EU instruments show that observatory-style infrastructures can work, but they also reveal clear gaps in coverage for advanced materials. The EU Observatory for Nanomaterials (EUON)⁶² aggregates information from REACH registrations, the EU nanomaterials catalogue for cosmetics, national inventories and dedicated studies to increase transparency about nanomaterials on the EU market, including their uses, safety information and regulatory status. Similarly, the SCIP database under the Waste Framework Directive collects notifications on articles containing substances of very high concern (SVHCs) with the aim of ensuring that information on hazardous substances is available throughout the product life cycle, including at the waste stage⁶³.

⁶² [European Observatory for Nanomaterials](#)

⁶³ <https://echa.europa.eu/scip-database>

These tools, however, are focused on substances, and are either limited to nanomaterials or to Substances of Very High Concern. They do not systematically track volumes, uses, progression through technology readiness levels, or innovation barriers across the broader landscape of advanced materials.

By way of contrast, the Raw Materials Information System (RMIS) demonstrates how a cross-cutting knowledge platform can support EU policy. It provides material system analysis and dashboards on raw materials flow over the entire life cycle, from extraction through use to end-of-life, and supports assessments of security of supply, circularity and criticality for legislation on Raw Materials and Critical Raw Materials⁶⁴. A Materials Impact Observatory would play a similar role for advanced materials and Safe and Sustainable by Design: not duplicating the Raw Materials information System or REACH/SCIP, but complementing them with a focus on functional materials, products, deployment across technology readiness levels, and the associated exposure and risk profiles. It would aggregate and harmonise data from existing registers (REACH, EUON, SCIP), Horizon Europe and PPP reporting, open innovation test beds, digital product passports and sectoral product regulations, re-using existing registers with standardised formats, protecting commercial secrecy while still enabling policy steering.

An explicit focus on mid-to-late technology readiness levels is critical. Many advanced materials stall at intermediate levels because their development is not aligned with customer and investment readiness, and because scale-up infrastructure, certification and regulatory preparedness lag behind. The Observatory would systematically track not only technological readiness but also deployment barriers like absent test methods (SAPEA, 2026), regulatory uncertainties, standardisation gaps, or the lack of qualified production lines – and link these to real market volumes and use patterns.

This would provide partnerships, Joint Undertakings and funding programmes with concrete evidence about where support is most needed, and where Safe and Sustainable by Design requirements or test methods need to be updated, enabling adaptive governance consistent with the EU's "evaluate first" approach and with the monitoring and evaluation tools highlighted in chapter 6 of the SAPEA report.

External evaluations and market studies further justify a permanent observatory instead of ad-hoc projects. The Commission's study of the EU market for nanomaterials had to compile data on substances, uses and industry segments from multiple fragmented sources to obtain even a partial picture of the market (ECHA 2022). This approach is costly, slow and often incomplete. An Observatory with continuous data inflows and standardised formats could replace sporadic studies with a stable monitoring regime, improving the timeliness and coverage of

⁶⁴ <https://rmis.jrc.ec.europa.eu/>

information used for exposure models, life-cycle sustainability assessment and SSbD dashboards.

The Observatory would also align with the Materials 2030 Manifesto and Roadmap, and its call for a common framework and data-driven ecosystem for advanced materials connecting upstream developers, downstream users and policymakers to support the green and digital transitions⁶⁵. By providing structured, FAIR+ and interoperable data on material flows, deployment and impacts, the Observatory would be a concrete institutional pillar of the Materials Commons, directly supporting the implementation of Safe and Sustainable by Design, and the monitoring needs of the 2024 Communication on Advanced Materials.

A further justification concerns the strategic and dual-use nature of many advanced materials. Like DARPA in the US, the European Defence Fund (EDF) finances cooperative R&D and development of critical defence technologies, including advanced materials, while the new Security Action for Europe (SAFE) instrument is set to mobilise a significant contribution for joint defence procurement and industrial production across the EU. Establishing structured communication lines between the Materials Impact Observatory, EDF/SAFE governance and the European Defence Agency would ensure that information on materials developed and scaled in defence programmes (within security constraints) can inform civil SSbD criteria, exposure assessments and standardisation, and vice versa. This would help avoid regulatory blind spots for dual-use materials, while also supporting resilience and sovereignty objectives and informing “Made in Europe” capacity planning for critical materials and components.

Finally, the Observatory would improve transparency and public trust. Monitoring data can feed directly into risk prioritisation, classification and regulatory refinement, and transparency about the use of advanced materials can foster public confidence and acceptance. By feeding aggregated indicators into exposure/risk and SSbD dashboards, interoperable with Environmental Product Declarations, digital product passports and open sustainability databases, the Observatory would give citizens, regulators and investors a clearer view of both the benefits and the risks of advanced materials.

⁶⁵ https://research-and-innovation.ec.europa.eu/document/download/fa1f3f35-7cac-49c7-a212-366879848f4c_en?filename=advanced-materials-2030-manifesto.pdf

Recommendation 4

Invest to expand EU strengths in research and innovation on advanced materials

Alignment with EU priorities and values requires investing in the development of societally beneficial advanced materials that minimise reliance on rare materials, reduce energy consumption and greenhouse gas emissions, and can substitute oil-based materials. To be able to do this, additional efforts are needed in promoting basic and applied research to develop innovations that improve efficiency of materials use (enabling circularity), reduce pollution, and minimise the impact of new materials on (human, animal, plant) health and environment. The EU has traditionally been a world leader in materials science, enabled through both strong support under national programmes and the EU framework programmes for R&I, the availability of world-class research infrastructures, and databases and digital tools (SAPEA, 2026). Eight of the world's 25 top materials science institutions in QS University Rankings are European. Education and skills are key enablers for a resilient advanced materials R&I ecosystem, and the Draghi report underlines skills shortages and gaps as critical for EU's competitiveness. Specialised education and training programs could help foster a more unified approach and promote a shared understanding of the methodologies and best practices required for the development, production, characterisation, application, and end-of-life management of advanced materials. As well as catering to the needs of the current workforce, these educational initiatives should also inspire a new generation of professionals.

On the academic side, the EU ranks third globally (behind China and India, but above the US), producing fewer than 2 million Science, Technology, Engineering, and Mathematics (STEM) graduates in 2023⁶⁶. Europe is currently short of 2 million STEM professionals, and the gap is widening⁶⁷, increasing the risk that the EU falls further behind in the global advanced materials race. There is also a significant gender gap, with almost twice as many men as women studying STEM subjects in both higher education and vocational training⁶⁸. This has a strong impact on the job market, leading to a lack of diversity and limiting the EU's potential for innovation.

Student education however is only half of the issue: according to future demographic projections, by 2050 Europe will face a 12% decline in its overall

⁶⁶ [Tertiary education statistics - Statistics Explained - Eurostat](#)

⁶⁷ [Europe is short 2 million STEM professionals](#)

⁶⁸ [Union of skills - European Commission](#)

labour force, with a concurrent loss of 1.5 million higher education students (Nadziak, M., & Figiel, K. 2025). To counter this trend, the EU needs more lifelong learning initiatives that directly address the skills gap. As careers may now span fifty years, the human capital base must be renewed multiple times to avoid skills obsolescence and ensure a continuous supply of skilled professionals along the evolving advanced materials value chain.

R 4.1 Support blue sky research and research areas that do not yet have clear applications

A range of emerging and fundamental research areas such as quantum technologies, polymer-matrix composites and oxide ceramics have not yet translated into direct, near-term products or services. In other cases, the challenge is even more fundamental: a mature market has not formed at all, as is the case for space-based solar power and brain-inspired computing. But the absence of obvious applications or established demand should not be interpreted as a lack of value – such domains often sit on the frontier where breakthroughs are made, and continued investment could enable the EU to convert early scientific gains into long-term technological sovereignty, industrial capacity and global influence. Many of today's most influential industries, including semiconductors, satellite navigation and advanced pharmaceuticals were born out of decades of curiosity-driven work, the value of which was not immediately obvious at the time. Blue sky research is therefore highly strategic: it creates a pipeline of ideas, methods, and capabilities that can be mobilised when technological windows open, crises emerge, or demand for solutions to new societal needs accelerates.

As stated in the SAPEA report, strong support for fundamental research is one of the EU's structural strengths, particularly through instruments such as the European Research Council (ERC). Preserving and expanding this strength requires sustained commitment to blue sky research in areas that are high-risk, interdisciplinary, and exploratory by nature. Such funding is essential, both to generate new knowledge, and to build the talent base, research infrastructure and scientific networks that enable rapid translation once applications and markets have crystallised. It also safeguards Europe's ability to attract and retain excellent researchers, enables mobility and cross-fertilisation across disciplines, and underpins the scientific credibility that makes Europe an influential partner in global research collaboration. The methodological foundation it creates in metrology, modelling, materials characterisation, computing and data infrastructure enables faster, cheaper and more reliable applied innovation. Without this strong foundation, downstream innovation becomes more dependent on external knowledge production and standards, components and intellectual property developed elsewhere.

To maximise impact, support for blue sky research must be accompanied by funding designs that recognise the specific timelines and uncertainties of frontier science. Researchers need stable, long-term tools that enable them to pursue ambitious questions without premature pressure to demonstrate short-term returns, assessment approaches that reward quality, originality and learning rather than near-term “deliverables”, and portfolio-based thinking that accepts that not every project will be successful.

Several research areas already provide a potential competitive edge for Europe and are candidates for strategic reinforcement, even in the absence of short-term commercial pathways. Targeted support for these areas – along with open-ended funding for discovery-driven science – will help ensure that the EU remains a global leader. Europe is well-positioned in domains such as biomaterials and advanced manufacturing, sustainable and high-performance composites, next-generation ceramics for extreme environments, photonics and quantum systems and emerging computing paradigms that can redefine energy efficiency and security in digital infrastructure (see BOX 1). These areas are linked to strategic European priorities, including the clean industrial transition, flexible energy systems, secure communications and high-value manufacturing. They also provide opportunities for standard-setting and the development of critical supply chains – both of which can translate scientific strengths into sustainable global impact.

At the same time, the EU must protect research spaces that do not immediately align with the current industrial agenda, as disruptive opportunities often emerge from unexpected directions. Focusing too much on near-term market readiness risks undermining Europe's innovation base, discouraging scientific risk-taking and creating reliance on the technologies of today rather than tomorrow. A balanced approach is needed, combining open, investigator-driven programs that support curiosity-led discovery, strategically driven investments in areas where Europe can potentially lead, and mechanisms that enable promising results to be taken forward when actionable. This would strengthen Europe's ability to shape future technology trajectories, reduce dependencies in critical domains, and maintain a strong and diverse research ecosystem capable of responding to long-term societal challenges and unexpected shocks.

R 4.2 Increase the human capacity in advanced materials, offering opportunities for education and skills development in research, industry and regulation

Public investment in targeted capacity building can help offset both cuts in university and research funding, and the financial implications of reduced student numbers. New curricula are needed, allowing students to specialise in advanced materials development, thereby retaining cutting-edge research innovation

platforms in Europe, and creating a European skills pipeline for advanced materials. These training facilities should be coupled with open-access pilot lines, metrology labs, and certification hubs to offer hands-on experience and bridge TRL gaps.

The European Institute of Innovation and Technology (EIT) recently launched the European Advanced Materials Academy, to become operative in 2026. As a flagship EU initiative, the Academy aims to train 200 000 people by 2029, fostering new talent, supporting lifelong learning, and closing the skills gap in this field⁶⁹. The Academy will collaborate with Europe's foremost advanced materials associations and specialist institutions to deliver industry-oriented courses spanning the advanced materials value chain in areas such as digital materials modelling, additive manufacturing, AI applications and SSbD innovation.

Coordinate education initiatives

National and European initiatives are promising, but they are fragmented and lack coordination, which can undermine their results. We therefore recommend that the Commission should set up an observatory mechanism for advanced materials skills in collaboration with industry stakeholders. Member States should keep track of the available courses and the number of active students in advanced materials and make this data available for the EU, and the observatory in turn should use this data to map the advanced materials education offer, quantify the number of additional students and workers needed to anticipate skills shortages, helping curricula to evolve in step with industry standards.

Matching supply and demand for skills in the advanced materials sector presents specific challenges and opportunities. The skill set needed is interdisciplinary and includes direct skills in advanced materials and complementary areas such as AI, scale-up, process technology, and green and digital manufacturing. This can enable skilled professionals to transition effectively from a related field to advanced materials. Coordination efforts should take advantage of the inter-sectors synergies between existing training initiatives to avoid duplication and regional unbalances across the EU.

These cross-border governance actions could be implemented by the European Skills Intelligence Observatory, which is already proposed in the Union of Skills Communication⁷⁰.

⁶⁹ [European Advanced Materials Academy to train 200 000 people - Research and innovation](#)

⁷⁰ [Union of skills - European Commission](#)

Support lifelong learning

Reforms in the higher education system can have positive returns on the available labour market 5-10 years from now. For this reason, equal efforts should be taken to answer today's workforce shortages with upskilling and reskilling measures. Currently, less than 40% of the adult population take part in education or training, with low-skilled individuals participating the least⁷¹.

Industry-recognised micro-credentials offer a model by which companies and training providers can offer targeted re-skilling and upskilling programs to address emerging skills demands. The Commission should expand the use of micro-credentials as flexible learning solutions in line with the European approach⁷² to ensure that they are trusted, understandable, issued digitally and comparable across sectors and countries.

Attract, retain, and cultivate talent

Attracting more talent from outside the EU would help build up a qualified workforce for the advanced materials sector in the short term. In the global competition for talent, the EU is less attractive to skilled professionals than other OECD members such as Canada, the US and Australia⁷³. Favourable visa and admission policies are key drivers here, and targeted migration policy reforms, including streamlined visa procedures for critical job profiles would increase the attractiveness of the EU. On the academic side, the Choose Europe For Science initiative and its pilot Marie Skłodowska-Curie Action⁷⁴ should be leveraged to pull talented post-doctoral and early-career researchers into Europe's advanced materials R&I landscape.

Actions should also be implemented to retain and cultivate talent within Europe. The prevailing model of centralised R&I hubs, although offering localised efficiency gains, creates a degree of strategic vulnerability. In the face of geopolitical uncertainty, supply chain disruptions, and fragmented global systems, the concentration of R&I capacity in a limited number of major cities renders the broader continent susceptible to risk and exacerbates brain drain. To mitigate this vulnerability, Europe should prioritise the attainment of long-term distributed resilience over short-term efficiency gains (Nadziak, M., & Figiel, K. 2025). This can be achieved by deliberately distributing high-tech infrastructure – including Knowledge Transfer Offices, Research and Technology Organisations, and regional innovation clusters – to peripheral regions. By anchoring talent locally and

⁷¹ [Adult learning statistics - Statistics Explained - Eurostat](#)

⁷² [Council Recommendation of 16 June 2022 on A European approach to micro-credentials for lifelong learning and employability \(2022/C 243/02\)](#)

⁷³ [Talent Attractiveness 2023 | OECD](#)

⁷⁴ [Choose Europe: advance your research career in the EU](#)

fostering collaborative networks between industry, academia, and research institutions, this strategic approach could leverage regional diversity as a catalyst for autonomy, transforming previously disadvantaged areas into strategic nodes capable of assuming leadership roles in specialised areas like energy storage, quantum materials, or biomaterials, thereby enhancing the continent's overall innovation ecosystem and competitiveness.

R 4.3 Reduce fragmentation of the EU R&I funding landscape

In the absence of a joint and coordinated strategy, public investment in R&I for advanced materials remains highly fragmented, limiting the EU's ability to strengthen competitiveness and build long-term resilience. Funding streams across Horizon Europe, national programmes, and mission-driven initiatives often operate in parallel rather than in concert, resulting in duplication, gaps, and missed opportunities for scale.

At the same time, geopolitical pressures have accelerated the shift towards R&I programmes that support competitiveness and defence, both through industry-driven research and new instruments such as the European Defence Fund and the European Competitiveness Fund. Advanced materials sit at the heart of these domains. This changing funding landscape should be viewed as an opportunity – a chance to build stronger institutional bridges between fundamental research, industrial innovation, defence-related needs, and civil applications of advanced materials. A concerted approach will also make it possible to keep a focus on EU priorities like the European Green Deal, the twin transition and strategic autonomy. For example, research and development can be targeted toward the substitution of critical raw materials in the energy sector (Ierides et al., 2025).

Taken together, these measures can transform a patchwork of programmes into a genuinely strategic R&I ecosystem that accelerates innovation, strengthens competitiveness, and ensures that advanced materials are developed safely, sustainably, and with clear societal benefit.

R 4.4 Secure access to critical raw materials for research into advanced materials through strategic alliances with like-minded partners outside the EU

Technological advances in circularity, substitution and improved recyclability will reduce pressure on primary supply, but they are unlikely to eliminate the need for critical raw materials altogether. Key applications like batteries, magnets, power electronics, aerospace and defence face a combination of fast-rising demand, long product lifetimes and imperfect collection systems, and secondary raw material supplies are unlikely to scale in time. Accordingly, the EU's strategic objective has

shifted from a narrow recycling solution to a broader resilience agenda where increased domestic capacity across the whole value chain is combined with diversification and de-risking of external dependencies, as set out in the European Critical Raw Materials Act⁷⁵.

Securing access at scale also requires a pipeline of investable projects and faster delivery, with strategic projects, more predictable permitting, and Member States encouraged to establish single points of contact. In parallel, the governance dimension is being strengthened through EU-level structures, including the establishment of a European Critical Raw Materials Board to support implementation tasks.

As Europe will remain dependent on trade, partnerships will be needed to actively shape supply conditions, in line with the resource diplomacy set out in the Preparedness Union Strategy Action Plan, the EU's broader approach under Global Gateway, and strategic raw-materials partnerships aimed at diversifying sources while supporting value creation in partner economies⁷⁶.

Given that critical raw materials policy now spans industrial strategy, trade, external action, environmental permitting, circular economy and security/preparedness, there is now a real risk of fragmented (or even contradictory) implementation. To counter this danger, one practical step would be to institutionalise regular cross-service coherence checks that connect evolving risk assessments and stress tests, the pipeline of strategic projects and financing tools, the international partnership priorities under resource diplomacy, and circular economy measures designed to reduce leakage and increase supplies of secondary raw materials. Structured coordination along these lines, anchored in the governance system set up under the Critical Raw Materials Act and rolled out through repeated cross-DG reviews cycle would reduce silo effects, help ensure that initiatives work together, and improve the EU's ability to act quickly in the face of supply disruptions and geopolitical shocks.

R 4.5 Secure access to low-cost, green energy for material science, including for artificial intelligence

Energy is a core enabling input for advanced materials research and manufacturing, from furnaces and thermal treatment for ceramics to thin-film deposition and the scaling up of industrial production. The rapidly growing electricity needs associated with AI – including for training and running large models used in materials discovery, process optimisation and Digital Twins – further amplify this dependency, exposing R&I actors to

⁷⁵ https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan/european-critical-raw-materials-act_en

⁷⁶ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/story-von-der-leyen-commission/stronger-europe-world_en

electricity price volatility and grid bottlenecks. We therefore recommend that the EU treat low-cost, reliable, green electricity as strategic research infrastructure, so that researchers and industry have predictable access to low-carbon power to sustain an advanced materials R&D environment.

The European AI in Science Strategy and the RAISE initiative already aim to pool resources critical to AI such as computing power, data, talent and funding, and secure researchers' access to high-end computing. The aim is to secure dedicated access to AI gigafactories and cooperate with EuroHPC structures so that EU-funded research projects can reliably use frontier compute capacity for scientific applications, including for advanced materials⁷⁷. This approach should be supported, while ensuring that access is geographically inclusive (across Member States and regions), sector-agnostic (mobility, health, climate, security, etc.), and available for all TRLs⁷⁸.

AI Gigafactories alone however will not solve the core issues, unless they are embedded in an energy-secure design, as large compute facilities are constrained by grid connection, power availability and the ability to procure genuinely green electricity at competitive cost. The EU should therefore pair AI compute roll-out with energy measures that accelerate renewable generation and grid reinforcement where research and industrial clusters are located, enable long-term price stability through instruments and de-risking finance, and apply clear sustainability requirements including energy efficiency, heat reuse, and transparent low-carbon sourcing, so that scaling AI does not undermine decarbonisation goals⁷⁹.

Similar mechanisms could be envisaged to support energy access in advanced materials research more broadly. The Commission's Affordable Energy agenda and the emerging tripartite contracts concept that brings together public authorities/finance, clean energy developers and industrial off-takers could be strengthened and extended so that all materials R&D and demonstration facilities (i.e. and not only mature heavy industry) can benefit from a stable, affordable, low-carbon electricity supply⁸⁰.

In practice, this could include dedicated research and pilot production eligibility windows, coordinated procurement/aggregation for research campuses and industrial parks, and priority grid planning for strategic R&D infrastructures that serve Europe's industrial leadership in advanced materials and AI-enabled innovation.

⁷⁷ https://www.eurohpc-ju.europa.eu/index_en

⁷⁸ [European AI in Science Strategy - Research and innovation](#)

⁷⁹ <https://digital-strategy.ec.europa.eu/en/policies/ai-factories>

⁸⁰ [Action Plan for Affordable Energy: Unlocking the true value of our Energy Union to secure affordable, efficient and clean energy for all Europeans - Energy](#)

ANNEX 1

Methodology

The Group of Chief Scientific Advisors (GCSA) provides independent scientific advice to the to the European Commission (EC) to inform policy making. The advisors work closely with the Scientific Advice for Policy by European Academies (SAPEA) consortium, which collects expertise in natural, biomedical, and social sciences, humanities, and engineering from a network of more than 100 academies and societies across Europe. The GCSA is supported by an administrative/scientific group in the EC's Research and Innovation Directorate General (DG RTD). GCSA, the DG RTD group and SAPEA constitute collectively the Scientific Advice Mechanism (SAM).

In this framework, the GCSA has been asked to provide a Scientific Opinion on 'Advanced materials'.

The Group of Chief Scientific Advisors is asked to answer the following questions:

1. What contribution can advanced materials bring to EU's strategic autonomy? This should cover:

a) Research areas in advanced materials reflecting EU core strengths, and with highest potential impact on industrial competitiveness and gaps where the EU should put additional efforts, and

b) Crosscutting research challenges on safe and sustainable advanced materials for the circular economy (design, development, characterisation, processing, production and product integration).

2. How can the cross-fertilisation of innovation in advanced materials be enhanced? This should cover:

a) Identifying mechanisms to tap the potential of new innovative functionalities across sectors and applications, and to stimulate new business models and innovation markets, and

b) Facilitating alignment and feedback loops between basic research and industrial needs for advanced materials, and supporting uptake by industry.

The Group should identify best practices, pitfalls and roadblocks to avoid.

The work of the scientific advisors was supported by SAPEA, which provided the scientific evidence in a state-of-the-art report underpinning the Scientific Opinion (SAPEA, 2026). SAPEA established a working group of experts to write the Evidence Review Report. The evidence was discussed in meetings of academic

experts and policy experts and practitioners (Annex 4). SAPEA also organised an expert workshop with independent scientific experts.

The SAM Secretariat produced an overview of the policy landscape relevant for advanced materials, helped the GCSA organise discussions on the draft recommendations with policy experts of the EC, with scientific experts in a 'sounding board meeting', and a stakeholder meeting. In these meeting the SAPEA Working Groups members and the GCSA presented the output of the SAPEA Evidence Review Report and the specific topics addressed in the Scientific Opinion.

Therefore, the present Scientific Opinion was informed by the following, as well as by additional reports and literature as references in the text of the opinion:

- Scoping paper: 'Cross sectoral evidence-based governance for One Health in the EU', (SAM 2025).
- Evidence Review Report carried out by SAPEA (SAPEA 2026)
- Sounding board meeting November 2025
- Policy Officers meeting January 2026
- Stakeholders meeting January 2026

Some AI tools were used in earlier drafts of this Opinion for language editing purposes and to check for repetition. The GCSA takes full responsibility for the contents of the final text.

ANNEX 2

Scoping paper

Scientific Advice Mechanism

European Commission's Group of Chief Scientific Advisors

Scoping paper

Working title

«Advanced Materials»

March 2025

The issue at stake

Advanced materials are defined by the Organisation for Economic Cooperation and Development (OECD) as materials that are designed to have new or enhanced properties, and/or targeted or enhanced structural features, leading to specific or improved functional performance⁸¹. They can, for example, substitute harmful substances or critical raw materials that are commonly used in industry. Moreover, they play a central role in the development of innovative products, with a various applications ranging from energy-efficient construction materials to advanced medical devices. They also play a central role in the electronics' sector as they are essential in the development of next-generation semiconductors. As such, advanced materials can support the transition of our industrial environment as well as the transformation of sectors like energy, construction, mobility and electronics, and help drive the twin green and digital transition.

Advanced materials are present in diverse industrial sectors, as insulation material in construction, in medical devices in health care, as lightweight materials in airplanes or cars, as coatings for solar panels or wind blades for renewables, as well as in chips and in electronics.

As the rollout of the Green Deal, the circular economy and the digital transformation gather pace, demand for advanced materials will continue to grow worldwide. These materials will need to be circular by design to facilitate recyclability, safe to avoid hazards, and sustainable, to improve the environmental footprint of products. Consequently, ensuring access to advanced materials paired with appropriate regulation is key to strengthen the competitiveness of European industries and to contribute to the Clean Industrial Deal.

Europe's research ecosystem is currently too fragmented, and uptake of research in industry is generally poor. The design and the development of advanced materials present a high risk to investors, as future applications are difficult to predict. More investments are required to support high risk projects of strategic importance for industrial value chains in Europe. In addition, the integration of Artificial Intelligence (AI) and digital technologies in research and development has the potential to revolutionize the discovery of advanced materials

1. EU policy background

In the EU policy landscape, advanced materials are recognised as key enablers in the competitiveness challenge of European industries globally, and in the green

⁸¹ [Advanced Materials: Working Description | OECD Environment, Health and Safety Publications](#)

and digital transitions. In particular, they have the potential to substitute or reduce the need for certain critical raw materials (CRM), in line with the objectives of the Critical Raw Materials Act⁸². They are also a key component in driving innovation for clean energy technologies, providing support for the implementation of the Net-Zero Industry Act⁸³. In February 2022, seven major stakeholders signed a Materials 2030 Manifesto⁸⁴, which paved the way towards implementation of an Advanced Materials 2030 Initiative by hundreds of stakeholders, mainly researchers and innovators⁸⁵. The Materials 2030 Manifesto triggered a major discussion to give a more central role to advanced materials as a driver for prosperity in Europe. Following President von der Leyen's 2023 State of the Union address, "Advanced Materials for Industrial Leadership" became a priority for the Commission, with implementation led by the Directorate-General for Research and Innovation. A Communication on Advanced Materials for Industrial Leadership followed on 27 February 2024, setting out a strategy to create a "dynamic, secure and inclusive ecosystem for advanced materials in Europe"⁸⁶.

This Communication recognised the challenges that Europe is facing in the advanced materials R&I landscape, highlighting for example the fragmentation of R&I ecosystems, the gap between EU and US private investment in this area, low digitalisation levels in the design and development of advanced materials, and a lack of the necessary skills for the future. Overall, the increasing demand for advanced materials in Europe is facing major issues when it comes to the industrial uptake of innovations. Several initiatives have been proposed to target these gaps, with a view to:

- Better, smoother coordination between European and national research programmes, on the basis of a list of common research priorities focused on the actual needs (functionalities) of advanced materials. A new Technology Council for Advanced Materials should supply the necessary governance, bundling the discussions on priorities and, if possible, leading to a common investment agenda.
- Scaling up and increasing manufacturing capacity of advanced materials. This includes improving digitalisation of the R&I landscape and developing technology infrastructures.
- Increasing capital investment and access to finance. This includes 'Innovative Advanced Materials for EU (IAM4EU)', a new co-programmed public-private partnership under Horizon Europe, the integration of potential

⁸² [Critical Raw Materials Act - European Commission](#)

⁸³ [Net-Zero Industry Act - European Commission](#)

⁸⁴ [advanced-materials-2030-manifesto-Published-on-7-Feb-2022.pdf](#)

⁸⁵ [Materials 2030 Initiative](#)

⁸⁶ [Advanced Materials for Industrial Leadership - European Commission](#)

new important projects of common European interest (IPCEIs), increased development of start-ups with support from the EIC, and developing investments with EU instruments such as the Innovation Fund, the Strategic Technologies for Europe Platform (STEP), and InvestEU.

- Fostering the production and use of advanced materials, including through stimulating the market through public demand, developing skills through the launch of an Advanced Materials Academy, developing standards, and launching an analysis of the patent landscape and industry needs.

In July 2024, the new Technology Council for Advanced Materials, which aims to coordinate R&I policy across Europe, was established by a Commission Decision⁸⁷. It includes high level representatives from ministries in charge of research and sectorial/industrial policy of the Member States, R&I stakeholders, and the European Commission. Its first meeting took place on 15 November 2024⁸⁸.

On 8 December 2022, the Commission adopted a Recommendation on a ‘safe and sustainable by design’ framework for the manufacturing of chemicals and materials⁸⁹. This recommendation was referenced as a cross-cutting feature for future advanced materials, to promote the safety and circularity of advanced materials under the Advanced Materials’ Communication.

This Communication suggested focusing on a preliminary list of 4 first priority areas – energy, mobility, construction, and electronics. These priorities were identified after consultations with the Member States as being the most urgent in line with industrial and societal needs. On 29 November 2024, Ministers approved the Council conclusions on the Communication on Advanced Materials for Industrial Leadership⁹⁰. The Technology Council of 15 November supported considering adding health as a fifth priority area.

In the context of the new mandate of President von der Leyen, advanced materials have been identified as a priority. In her mission letter of September 2024, Commissioner Zaharieva was tasked with putting forward an Advanced Materials Act, to “support the research and innovation process through to manufacturing and deployment”⁹¹. Commissioner Zaharieva was also tasked to put forward a strategy to increase the uptake of AI by EU scientist and help set up a European AI Research Council, which can support R&I in advanced materials.

⁸⁷ [Commission Decision of 5.7.2024 setting up the high-level group ‘Technology Council for Advanced Materials’](#)

⁸⁸ [Technology Council for Advanced Materials holds Inaugural Meeting - European Commission](#)

⁸⁹ [Safe and sustainable by design - European Commission](#)

⁹⁰ [Competitiveness Council \(Research and space\) - Consilium](#)

⁹¹ [Ekaterina Zaharieva - Mission letter | European Commission](#)

In parallel, the Draghi report on competitiveness published in September 2024 suggested the creation of a partnership for advanced materials⁹².

Other initiatives related to advanced materials include the Graphene Flagship⁹³, the European Chips Act⁹⁴ and the upcoming Biotech Act.

Advanced materials are present in the work program of the European Innovation Council for 2025⁹⁵, through support to a high-risk project with an indicative budget of EUR 50 million.

Under Horizon Europe 2025-2027, the Commission will launch an 'Innovative Advanced Materials for Europe' (IAM4EU) public-private partnership, operated by the new international non-profit association 'Innovative Advanced Materials Initiative (IAM-I)'⁹⁶.

2. Request to the Group of Chief Scientific Advisors

In light of this policy background, the Group of Chief Scientific Advisors is asked to answer the following questions:

1. What contribution can advanced materials bring to EU's strategic autonomy?

This should cover:

- a) Research areas in advanced materials reflecting EU core strengths, and with highest potential impact on industrial competitiveness and gaps where the EU should put additional efforts, and
- b) Crosscutting research challenges on safe and sustainable advanced materials for the circular economy (design, development, characterisation, processing, production and product integration).

The Group should identify best practices, pitfalls and roadblocks to avoid.

2. How can the cross-fertilisation of innovation in advanced materials be enhanced?

This should cover:

⁹² [EU competitiveness: Looking ahead - European Commission](#)

⁹³ [Graphene research, innovation and collaboration | Graphene Flagship](#)

⁹⁴ [European Chips Act - European Commission](#)

⁹⁵ [Acceleration of advanced materials development and upscaling along the value chain - European Commission](#)

⁹⁶ [IAM-I | The Innovative Advanced Materials Initiative](#)

- a) Identifying mechanisms to tap the potential of new innovative functionalities across sectors and applications, and to stimulate new business models and innovation markets, and
- b) Facilitating alignment and feedback loops between basic research and industrial needs for advanced materials, and supporting uptake by industry.

The Group should identify best practices, pitfalls and roadblocks to avoid.

All advice on the questions above should preferably remain within the scope of the Commission Communication on Advanced Materials for Industrial Leadership (i.e. mobility, energy, construction, electronics and cross-cutting aspects), and also include health.

The role of digitalisation and AI should be considered by the Group.

All types of materials should be considered under the scope of advanced materials ('material agnostic').

The full opinion should be delivered by January 2026, and the Commission should be provided with intermediate outputs throughout the development of the opinion.

ANNEX 3

Previous Opinions

The European Commission's Scientific Advice Mechanism (SAM) has previously given advice on many issues that relate directly or indirectly to the challenges faced by the advanced materials sector in the EU. This chapter provides a summary of relevant Scientific Opinions and highlights interlinkages and continuity between SAM opinions.

The first question of the Scoping Paper driving this Opinion asks the SAM to discuss the contribution that advanced materials can bring to EU's strategic autonomy. During the Covid-19 pandemic, the EU experienced severe supply chain disruptions that endangered critical sectors of its economy like electronics, mobility, energy, construction, and health. These disruptions were related to the supply of critical raw materials from extra-EU countries, and the risks of future disruptions appear ever more present in the backdrop of the rising geopolitical upheavals.

These concerns were already addressed in the 2022 Scientific Opinion "Strategic Crisis Management in the EU" (CRISIS, 2022), which stressed that "critical infrastructures and economies rely heavily on supply chains for materials, flows of energy and resources, and skilled personnel. The current energy crisis clearly points to over-dependency on a few suppliers, chosen mainly based on cost, free market and efficiency criteria, as a major source of vulnerability. [...] Current crises are demonstrating the importance of both short- and long-term perspectives, balancing costs, benefits, and risks over long-time horizons rather than focusing on the immediate return on investments". In this context, a resilient European advanced materials sector can help de-risk these dependencies both on a short- and long-term perspective with the development of novel materials alternatives.

The urgent multi-dimensional crises should not narrow EU's vision and commitment to the green transition; rather, a holistic and comprehensive approach is needed, to consider all sectors impacted by CRM and where advanced materials could provide for. In the 2021 Scientific Opinion "A systemic approach to the energy transition in Europe" (ENERGY, 2021), the SAM reported on this necessity/inherent complexity: "keeping an eye on the 'big picture' should also ensure that competition for resources (including land use) between different sectors is kept at a minimum. Renewable energy technologies such as wind and solar require raw materials (such as rare earths, cobalt and borates) which are also crucial for the e-mobility, digital and defence sectors" (ENERGY, 2021). The opinion further argued that "substituting fossil fuels will require investing in renewable plants, grids and

pipelines, storage facilities (batteries, fuel cells), carbon-free energy carriers (blue and green hydrogen and methane), boosting the energy performance of buildings, efficient industrial processes and appliances, as well as ensuring new transportation technologies and smart systems” (ENERGY, 2021). These technologies are representative of sectors which are potentially, and in some cases already, impacted by advanced materials, underlining their relevance in Europe’s energy transition efforts.

Together with the security-of-supply and autonomy, materials recycling and circular economy “remain key issues as we change from fossil fuels to reliance on other materials” (ENERGY, 2021). While circular economy and recycling of materials present challenges, which will be potentially exacerbated by the increasing manufacturing complexity of advanced materials, they “offer an opportunity to improve resource and energy efficiency throughout Europe” and “will contribute to lowering energy demand, but may be even more important for the re-use of raw materials needed for e.g. batteries” (ENERGY, 2021). Today, the EU has the chance to invest in a safe and sustainable by design approach to materials development, supporting a model that will benefit its citizens safety, increase consumers adoption, and help Europe reach its green transition’s objectives.

Computational and data-driven methodologies are essential to enable faster materials discovery, clearer traceability, and earlier risk screening of advanced materials, all of which can reinforce competitiveness and even shape standards around the globe. The 2024 Opinion “Successful and timely uptake of artificial intelligence in science in the EU” (AI, 2024), argued strongly for the need to accelerate the use of AI in research, signalling that “AI may usher in a revolution in materials science” (AI, 2024).

The Opinion recommended to “prioritise AI research with major benefits for EU citizens. Consider supporting the development of AI considering human values and objectives and specialised to address personalised health, advanced materials, social cohesion, the European Green Deal or the Destination Earth project”. Indeed, the present Opinion recognises the need to integrate digitalisation, AI and computational methods for accelerating safe-and-sustainable advanced materials research and commercialisation, and supports the creation of data spaces for findable, accessible, interoperable, and reusable data. In this regard, the 2024 Opinion recommended to “develop and deploy frameworks, including flexible dedicated funding mechanisms for research with AI, that evolve with the fast-paced and dynamic advancements of AI to support and strengthen the use of AI in research” (AI, 2024).

High-quality, FAIR+ data is foundational for material science research, but “many current AI models perform poorly due to poor data used to train them. This is due to low input data quality, failure to update the model, and inherent differences

between training data and real-world population.” (AI, 2024). The Opinion then recommended to “Improve quality standards of AI systems (i.e., data, computing, codes) and provide fair access for all researchers working on and with AI research” (AI, 2024). One way to do this is to “support scientific research for reaching consensus on standards for metadata and methods to track how data is collected, selected, documented, and processed” and “ensure that researchers have access to those standards so that they can comply with them in their work” (AI, 2024).

Powerful datasets are currently locked within private data spaces that hinders collaboration and synergies in the European research ecosystem. To prevent external actors from taking advantage from EU’s R&I efforts for their own interests, data security concerns must be tackled decisively. Calling back to the H2020 Program Guidelines on FAIR Data, the AI 2024 Opinion pushed to “make data ‘as open as possible and as closed as necessary’ when researchers and scholars share data with the private sector and non-EU countries” (AI, 2024). This issue is addressed by the present Opinion, proposing a tiered approach to access safe and trusted European data spaces. This will encourage secure data sharing between researchers, regulators, industry and other stakeholders, which will ultimately benefit innovation and regulatory preparedness.

ANNEX 4

List of Additional Experts Consulted and Stakeholders

Sounding Board Meeting Participants

Name	Current Institutions
Costas CHARITIDIS	School of Chemical Engineering, National Technical University of Athens
Esther HURTOS	Fundacio EURECAT, Spanish Research and Technology Organisation
Mary RYAN	Imperial College London
Mohammad Reza SAEB	Department of Polymer Technology, Gdańsk University of Technology
Christian SERRE	Institute des Matériaux Poreux de Paris, Centre National de la Recherche Scientifique (CNRS)
Philip SHAPIRA	University of Manchester
Tejs VEGGE	Department of Energy Conversion and Storage, Technical University of Denmark

Stakeholder Meeting Participants

Name	Current Institutions
Andreas FALK	BioNanoNet (BNN)
Charanjeet SINGH	Centre for Process Innovation (CPI)
Cornelia PARTSCH	European Construction and sustainable built environment Technology Platform (ECTP)
Diana POTJOMKINA	Science Europe (SE)
Dorota A. PAWLAK	ENSEMBLE3 (Centre of Excellence for nanophotonicS, advancEd Materials and novel crystal growth-Based technoLogiEs)
Eberhard FALCK	International Raw Materials Observatory (INTRAW)
Emma STRÖMBERG	Swedish Environmental Research Institute (IVL)
Ennio CAPRIA	European Synchrotron Radiation Facility (ESRF)
Eva SCHILLINGER	Innovative Advanced Materials Initiative (IAM-I)
Gerhard GOLDBECK	European Materials Modelling Council (EMMC)
Giovanni GENOVESE	SEMI Europe
Marco FALZETTI	EuMaT (European Technology Platform for Advanced Engineering Materials and Technologies)
Pascal DI CROCE	European Lime Association (EuLA)
Ricardo DEL VALLE	Bax Innovation
Roger DOOME	Industrial Minerals Europe (IMA Europe)
Stephan RAU	Wirtschaftsverband der deutschen Kautschukindustrie eV (wdk)
Sean KELLY	Nanotechnology Industries Association (NIA)
Peter GUMBSCH	Karlsruhe Institute of Technology (KIT)

ANNEX 5

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Advanced materials are designed to deliver superior performance for specific functionalities. They are essential for Europe's autonomy, competitiveness, and resilience. However, even though Europe has a strong foundation in science and regulatory practices, structural challenges hinder the process from discovery to safe, sustainable and competitive use.

This Scientific Opinion by the Group of Chief Scientific Advisors (GCSA) provides recommendations on how advanced materials can support EU strategic autonomy, and on how the cross-fertilisation of innovation can be enhanced in this sector.

It emphasises the importance of prioritising core EU values such as safety, sustainability, transparency and high production standards.

This Opinion is published in the context of the Scientific Advice Mechanism (SAM) which provides independent scientific evidence and policy recommendations to the European institutions at the request of the College of Commissioners.

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