EU R&I and Health Policy to Tackle Global Challenges

Science in 2050: Alternative futures and lessons for today

Andrea Renda, Hien Vu, César Dro, Francesco Bernabeu Fornara, Leonie Kunze, Cosima Lenz, Hannah Macdonald, Rukudzo Nyoka, Linnea Paludan, Diana Senczyszyn, Katja Van der Meer, Petra Varkonyi and Timothy Yeung



SUMMARY

What will science look like in 2050? Drawing on a structured foresight process, this report explores four possible futures and asks what the EU must do now to thrive in any of them. The scenarios are shaped by two questions: Who funds and controls research- states or private actors? And is science organised centrally or in a distributed way?

In 'Grand Project State', science revolves around state-directed megaprojects addressing defined priorities at continental scale. In 'Platform Science', a handful of tech-industrial conglomerates operate the dominant research infrastructure. In 'Commons Network', public funding flows into open, decentralised infrastructure used by universities, civic labs and NGOs. And in 'Frontier Archipelago', science fragments into start-ups, decentralised autonomous organisations, independent labs and individual researchers, funded by venture and community capital.

The window for action is open now. Europe's choice will shape which future emerges. Eight lessons should inform the EU's 2028–2034 Multiannual Financial Framework and the next Framework Programme. First, competitiveness and security are not enough; curiosity-driven research keeps Europe future-proof. Second, trust in science will be more precious, making metascience and the validation of AI-generated findings a priority. Third, a public R&I investment target of 3% of GDP would provide a solid foundation. Fourth, European Partnerships and clarity on the roles of the Framework Programme and the European Competitiveness Fund are essential. Fifth, talent will decide Europe's position in every future. Sixth, science must remain a global public good. Seventh, coordination across governance levels is vital to achieve critical mass. Finally, the Framework Programme remains the anchor for all of this.

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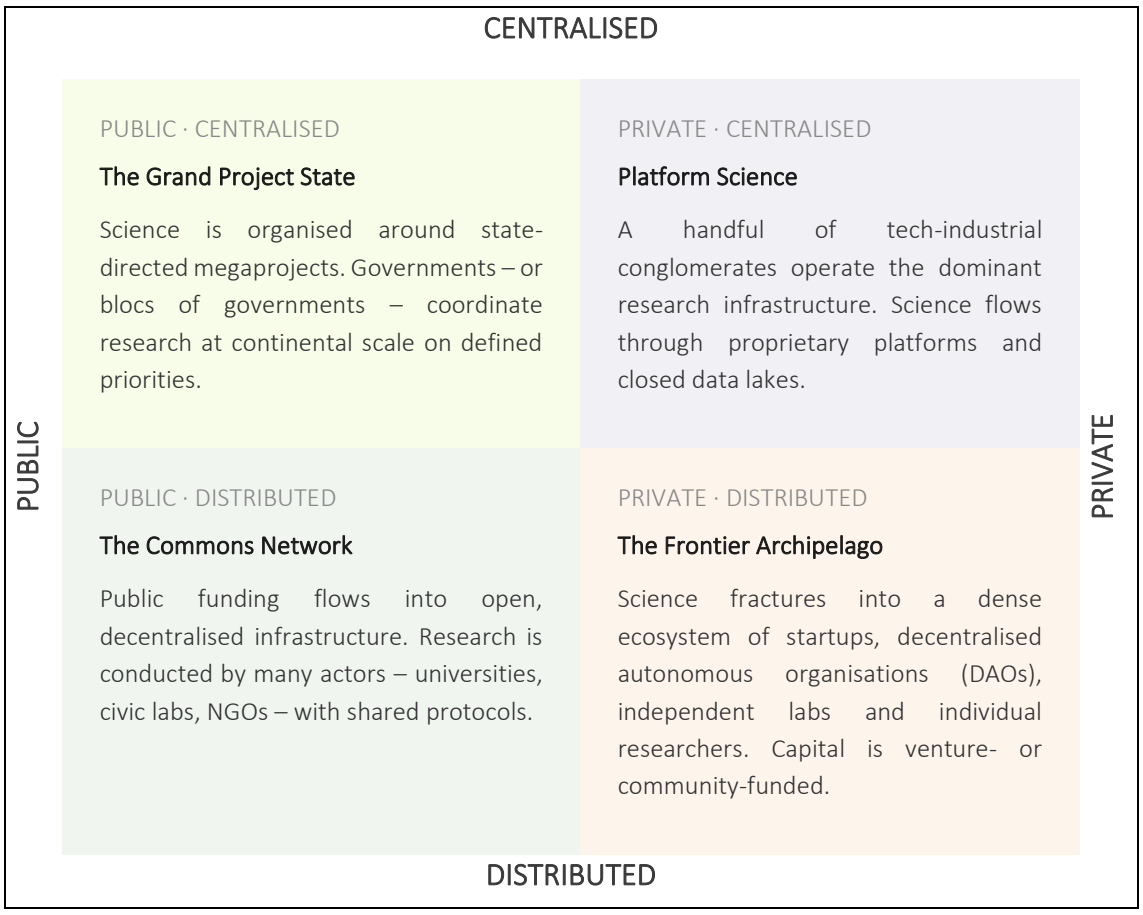
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Executive Summary

What will science look like in 2050? Will technology crack today's unsolved problems and spread the benefits widely? Will research remain public, open and verifiable, or become a matter of national security, its results closer to club goods than public ones? Will scientists still collaborate across borders, continents and disciplines? Will AI produce breakthroughs on its own, without giving humans the keys to how they were reached? And will Europe still be a leading player?

This report draws on a structured foresight process involving 33 experts across diverse fields, including science policy, digital technologies and AI, climate, energy, health, bioeconomy, chemical engineering, development and foreign policy. It sets out four scenarios for science in 2050 and asks what the EU must do now to thrive in any of them. The scenarios turn on two questions: who funds and controls research – states or private actors? And is science organised centrally or in a distributed way?



Each future brings different opportunities and risks for science and its governance. None is predetermined. The choices Europe makes now will shape which one materialises, above all: the ambition and composition of the 2028–2034 Multiannual Financial

Framework (MFF); the design, governance and ambition of the next Framework Programme; international research and innovation (R&I) collaboration; and proposals such as the European Innovation Act and the European Research Area (ERA) Act.

Across the four scenarios, we have identified eight lessons. Several are no-regret options that hold whichever future unfolds. The window is open now. Decisions taken in the coming negotiations will lock in budgets, instruments and partnerships for much of the next decade. Whether Europe reaches 2050 as a rule-taker in someone else's scientific system or as the architect of a trusted one will be decided in the current MFF and Framework Programme negotiations.

EIGHT POLICY LESSONS

1. **Don't bet everything on competitiveness and security**. A Framework Programme driven by these goals alone leaves Europe exposed in three of four futures. Missions and strategic priorities matter. But where private platforms or decentralised actors set the agenda, a narrowly targeted programme would leave Europe with little scientific base of its own to draw on. Protecting a meaningful share for bottom-up, curiosity-driven research makes the programme far more resilient. That research is where unexpected breakthroughs come from.

2. **Invest in trust**. Trust in science will remain a scarce resource. In every scenario, AI-accelerated discovery outpaces humans' ability to validate it. Without robust validation, findings risk being either accepted blindly or rejected reflexively. The Framework Programme should fund a dedicated stream on metascience, epistemics, validation of AI-based findings and ethics standards. This would turn Europe's strengths in research integrity and regulation into a distinctive advantage: becoming the place where AI-generated science is checked, trusted and reused.

3. **Commit 3% of GDP to public R&I**. This would give these ambitions a solid financial foundation, going well beyond the EU's existing 3% target, which counts public and private spending together. A public R&I spending target would signal long-term commitment and triggers predictability. It would also ensure Europe can pursue its own priorities in futures where private actors would not.

4. **Leverage beyond the public purse**. Public money alone won't suffice in any scenario. Partnerships, including Joint Undertakings, are the hinge instrument

for drawing in funding and capacity from the private sector, philanthropy, associated and partner countries, and society, and they need a bigger budget. The roles of the Framework Programme and the European Competitiveness Fund (ECF) must also be clarified. A clear division of labour would reduce fragmentation and give partners a stable entry point.

5. **Back talent**. Investing in research careers, working conditions and human-centred research in the age of AI pays off in every scenario. Whichever actors dominate in 2050, Europe's ability to attract, train and retain researchers will decide whether it shapes the system or merely adapts to it. A strong ERA Act today can pave the way for an 'ERA Act 2.0' that unlocks the fifth freedom: the free movement of researchers, knowledge and data across the Union.

6. **Guard science as a global public good**. Open knowledge, climate and health are underprovided in every future, especially where private players or rival blocs dominate. The EU should use the Single Market and its regulatory power to keep knowledge critical to grand challenges accessible; keep the Framework Programme open to associated and partner countries; and lead multilateral agreements that shield science from geopolitical rivalry. Doing so would also strengthen Europe's standing as a partner of choice for countries wary of dependence on rival blocs or dominant platforms.

7. **Align across levels**. Joining up R&I policy across EU, national, regional and local levels pays off in three of four futures. It brings agendas together, mobilises critical mass in funding and creates synergies. Fragmented efforts dilute impact. Coordinated ones let Europe compete at scale while preserving the diversity of its research landscape.

8. **Anchor it all in the Framework Programme**. It remains central in most scenarios, and its success depends on building all of the above into its design and implementation. Treating it as a strategic, future-proof instrument, rather than one budget line among many, is among the most consequential choices Europe can make.

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1. INTRODUCTION

Europe stands at a critical juncture for R&I. Negotiations on the 2028–2034 MFF and the discussions on Horizon Europe remain highly complex, particularly with regard to the budget, governance and alignment of scientific excellence with EU strategic priorities. A key issue is the programme's close link with the new ECF, which is designed to support EU competitiveness from research to market, shaping how research is translated into innovation and deployment. The expected ERA Act and the proposed European Innovation Act, which are advancing in parallel, aim to address both ends of the R&I chain: how research is organised and funded across Europe, and how its results are turned into competitive innovation. These are complemented by a growing set of sector-specific initiatives aimed at building European technological capacity, including the European Biotech Act proposed in December 2025 and the June 2026 Technological Sovereignty Package.

Together, these policy streams provide a clear vision of the EU's R&I policy agenda, one that is closely linked to its strategic priorities such as competitiveness, autonomy and security. The recent State of the Union 2026 speech emphasises these areas as the EU's strategic priorities. Governments now treat research capabilities as strategic assets comparable to military or economic power. Security concerns increasingly shape research priorities, funding flows and international collaboration. Dual-use research, critical supply chains and technological sovereignty are no longer niche concerns; they are central to how nations and blocs organise and prioritise their R&I investments.

Yet, the seven-year horizon, while ambitious, is insufficient for advancing the European R&I agenda to address wider issues. Concerns are being raised around the shift of R&I policy from sustainable development goals and global challenges towards strategic areas. The current proposal has not clarified the openness of Horizon Europe to Associated Countries and non-EU countries. Furthermore, EU funding is insufficient: it is challenging to reach critical mass of R&I funding by leveraging Member States and private resources. Additionally, private actors, start-ups, cities and citizens are increasing their influence in advancing R&I to address societal challenges.

At the same time, research institutions, scientific norms, governance structures and technological capabilities evolve over decades. The decisions made will interact with technological change, geopolitical shifts and unforeseen crises in ways that will only become apparent in retrospect. This calls for a longer-term perspective that asks not only how the R&I landscape might look like by 2050, but also what choices Europe can make today to shape it.

Firstly, we are living in a world where foundational technologies are drastically changing the way we do science. The take-off of artificial intelligence, quantum computing, synthetic biology and digital twins is creating new opportunities for research, as well as new risks. These technologies will transform what science can achieve, who can engage in it and under what conditions. However, their trajectories towards 2050 remain uncertain: access may expand globally or concentrate further; governance could remain national or become multilateral; and their power could be used for public good or be exploited by private interests. Governments and citizens therefore face an increasing challenge in overseeing research quality and ethics, particularly in the context of AI-augmented (or AI-based) research.

Secondly, other drivers of change interact with and amplify the above shifts. Evolving global governance structures, a shifting geopolitical landscape, resource scarcity, health crises, climate disruptions and the increasing dominance of Very Large Online Platforms (VLOPs) significantly impact the future R&I landscape. No single policy lever can address this complexity.

By 2050, some of today's choices will prove visionary while others will appear outdated or counterproductive. Some of the most consequential questions that have yet to be answered comprehensively in the current policy calendar include: Which drivers will shape the future of science? What will R&I look like in 2050? What are the challenges and opportunities of each scenario? Do we have a preferred future for science? And what can be done today to prepare for these futures by 2050?

This report uses a strategic foresight approach to address these questions. Rather than making predictions, we explore what 'may yet happen' across a range of possible futures, each of which is coherent and self-consistent. We present four scenarios for 2050, structured along two critical dimensions:

- The governance of science: whether research is governed and funded by state or private actors.
- The distribution of science: how research is organised, being either concentrated in large institutions or dispersed among smaller, more independent actors.

The combination of these dimensions generates four markedly different worlds:

- The Grand Project State, in which research is coordinated at a continental or bloc level around strategic missions;
- Platform Science, where private conglomerates dominate research infrastructure and priority-setting;

- The Commons Network, a world of distributed public funding that supports open, participatory research ecosystems;
- The Frontier Archipelago, a world of decentralised private funding and tools that empower start-ups, DAOs and independent researchers.

Chapter two explains the methodology of the foresight exercise, from literature review and AI-based horizon scanning to expert consultation. Chapter three presents the key findings of the driver-vetting exercise. Chapter four presents the scenarios and discusses their implications for the global scientific enterprise and the EU's R&I strategy. Chapter five puts forward a set of policy actions that could be implemented either today within the context of the MFF negotiations, or more in the medium to long term, when certain conditions arise and favour the realisation of alternative scenarios.

2. METHODOLOGY

The study team relied on a structured foresight methodology, which combines desk research and expert consultation through a foresight workshop.

2.1. DESK RESEARCH

Drivers of change. We initiated our desk research by exploring the drivers (of change) that could shape the future of science towards 2050. Drivers are (emerging) issues and factors that create recognisable change across the environment in which an organisation operates. They can include social, technological, ecological, economic and political issues (often referred to as the STEEP framework). They serve as the basis for the development of strategic foresight scenarios. The driver identification exercise followed two parallel research streams.

- **Research stream 1: from megatrends to drivers**. We used the 14 megatrends identified by the EU's Joint Research Centre (JRC) as the starting point. As defined by the JRC, megatrends are 'long-term driving forces that are observable now and will most likely have a significant influence on the future'. Based on the megatrends and complementary desk research, our team identified an initial list of drivers that can potentially impact the future of science.

- **Research stream 2: AI-supported horizon scanning**. We used AI tools to scan three evidence corpora. The first were two curated corpora of foresight reports and policy documents that yielded direct drivers. The third was a keyword-based OpenAlex corpus of scientific publications related to R&I. In this corpus, we used AI to extract topics (i.e. emerging themes and drivers). We then clustered and filtered the resulting topics to identify candidate drivers, which were merged with the drivers from the first two corpora, then scored and shortlisted across multiple dimensions:

    - Frequency (how often the driver appeared in the corpora)
    - Source diversity (the driver's distribution across the three corpora, emphasising drivers evenly distributed in multiple corpora as opposed to concentrated in specific areas)
    - Authority (whether the drivers were mentioned by authoritative sources – policy – as opposed to foresight or academic ones; when all three mention them, the dimension is valued higher)
    - Recency (how recently the driver was mentioned, from the last publication year)

- Foresight density (how often the driver was mentioned in the Foresight corpus)
- Large Language Model (LLM)-evaluated relevance (Claude Haiku): the model evaluated whether each signal had a direct impact on the way research and innovation is performed or produced.

Driver pathways. Once the drivers were identified through the two research streams above, the study team explored different pathways that they could follow toward 2050. Each pathway could be classified in one of three ways:

- *Dominant*: the expected development pathway based on current data and expert opinion
- *Deviant*: an alternative development trajectory that the driver might inherit due to external factors
- *Disruptive*: a driver trajectory that has a great potential impact but is highly unlikely (i.e. a 'wildcard'), and/or could only be caused by a major event whose implications would be far ranging across many aspects of the environmental conditions.

Connections between driver pathways and the R&I landscape. We assessed how each driver trajectory could potentially be connected with the future research and innovation landscape. The connection can be bidirectional, reflecting the impact of a given driver on the R&I agenda, and vice versa.

Scenario sketches. The research team pre-developed scenario sketches featuring the main elements of the R&I landscape. They are built on two main core drivers (i.e. axes), forming a quadrant of four scenarios. The first core driver (the axis) involves the governance of science, answering whether the public or the private sector funds and controls research. The second represents the scientific enterprise dimension, measuring how research will be organised in 2050 – either in a centralised or distributed way. The combination of these two axes allowed the scenario sketches to contain unique elements, with high uncertainty and high impacts on research and innovation.

2.2. FORESIGHT WORKSHOP

Scenario development. During the workshop, the experts fleshed out the scenarios by mapping the identified driver pathways to the scenario sketches. They did so by answering the following questions: (i) Which driver pathway fits best into this scenario? And how? (ii) Are there any driver pathways not presented in CEPS's pre-identified list that would fit this scenario well? If so, how?

Scenario visioning. Once the scenarios were developed, the participants explored the opportunities and challenges that each one can pose for the future of science. They also identified the stakeholders or population groups who would be most affected by the scenario and those who would play a key role.

A backcasting and wind tunnelling exercise. Findings from the above activity provide inputs for a subsequent backcasting exercise. Against the identified opportunities and challenges, in each scenario, experts worked from the future 'backwards' in time, defining actions that different stakeholders need to take to best prepare for and respond to different issues that might arise by 2050. They also examined possible obstacles and opportunities to implement each action.

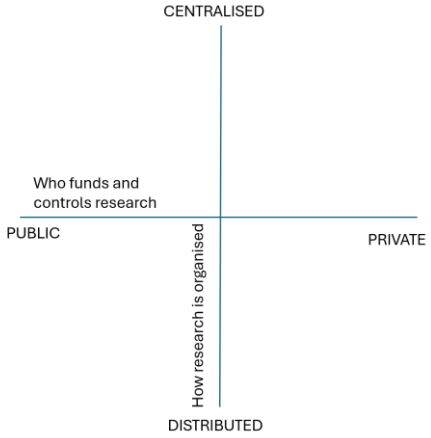
Experts provided inputs through answering these questions: *What would optimal EU R&I policy look like in this scenario, and what should its main objectives be? What are the key milestones to achieve these objectives? What are the main concrete actions that can contribute to delivering these milestones? Who plays the key roles in taking this action?*

Lastly, the workshop participants assessed the performance of the identified actions through a wind tunnelling exercise. This activity examined the plausibility and utility of each action under each scenario's future STEEP conditions. It resulted in the identification of a set of *robust* actions (i.e. actions that are effective and feasible in the majority of the four scenarios), partly robust actions and contingent actions (i.e. action is either neutral, not possible or causes new challenges in most scenarios but leads to important and desirable impacts for one scenario). Experts did this through voting for the actions they considered robust across the four scenarios in the backcasting boards.

Wind tunnelling facilitates the identification of strategic actions that are robust against several scenarios and are thus more likely to foster organisational resilience. Based on the results from the wind tunnelling activity, the research team identified common strategic themes shared by the actions consistently assessed as robust across multiple scenarios.

3. DRIVERS OF CHANGE

Two core drivers and 12 other drivers contributed to developing the scenarios.



The first core driver (axis of the scenario quadrant) involves the *governance of science*, answering whether the public or the private sector funds and controls research.

The second core driver represents the *distribution* dimension, measuring how research will be organised in 2050 – either in a centralised or a distributed way. These two core drivers form a quadrant of four scenarios.

Twelve other drivers could shape the future of R&I policy. They include:

- *'Access to foundational technologies'*. This driver features the advancement of general-purpose technologies such as AI, quantum computing, synthetic biology and digital twins. Those countries, institutions and players who control the infrastructure and cost of these technologies have a huge advantage in determining their access, which in turns impacts R&I funding flows and the way research is conducted, following either a concentrated or collaborative approach.

- *'Convergence of foundational technologies'*. Biotechnologies, AI and quantum computing could mutually reinforce or work in parallel in 2050. The mutual reinforcement of foundational technologies can accelerate discovery and open entirely new cross-disciplinary research fronts. However, if one technology collapses for lack of innovation, it can drastically affect the others.

- *'Open Science and R&I'*. This driver pictures whether open science remains a side approach or becomes a powerful paradigm in 2050. These different pathways could lead to either highly constrained access to R&I outputs and reproducibility, or the accelerated diffusion of scientific findings and an alternative crowd-based science model.

- *'AI in work'*. AI could augment work, replace work or even induce epistemic crises in 2050. These different trajectories affect the speed of doing research, the requirement level for upskilling and reskilling the workforce and public trust in science.

- *'Transformation of the multilateral order'*. The changing multilateral framework, the rising influence of regional and bloc cooperation, the reform of Western-

shaped organisations – all these factors could largely impact R&I priorities as well as dissemination, data sharing and IP rights. For example, in a world divided into power blocs, R&I priorities could become increasingly regionalised and competitive, with high risk of duplicating research infrastructures.

- '*Supply and demand for critical minerals*'. Our world in 2050 could observe a growing geopolitical competition for critical minerals, or a reduced dependence on these resources thanks to game-changing technologies. In both cases, R&I agendas have to shift significantly, focusing on innovation for resource efficiency and the circular economy, non-critical mineral-based battery technologies, novel materials or extraction technologies such as deep-sea mining.

- '*Securitisation of non-military affairs*'. Areas previously considered standard policy – public health, tech, regulation – could be framed as security matters, with governments embedding security logic across everyday policy areas. Consequently, R&I priorities could be redirected toward strategic interests, narrowing scope and increasing top-down control over research agendas.

- '*Geoeconomic competition and strategic dependency*'. This driver depicts how trade and economic dependencies are leveraged as geopolitical tools and shift R&I agendas toward strategic autonomy such as critical raw materials, domestic semiconductors, energy storage and pharmaceutical supply chains. Alternatively, our 2050 world could see multilateral rapprochement on minimum global rules in critical areas due to the recognition of a lose-lose scenario in geoeconomic confrontation. That could lead to ring-fencing of fundamental science to protect it from geopolitical instrumentalisation, agreed multilaterally.

- '*Changing lifestyles*'. Consumption growth and consumption inequality (e.g. between the extreme rich and the lower-income majority) could pull private sector R&I toward high-consumption sectors, luxury sectors, material efficiency and resource management.

- '*Platformisation of public discourse*'. VLOPs could become the hubs of public discourse, with algorithmic personalisation entrenching echo chambers. If not properly governed, they can be sources of disinformation and declining institutional trust, including in science. Regulatory packages like the EU's Digital Services Act (DSA) and Digital Markets Act (DMA) could minimise the social harm of VLOPs while maintaining their role as public discourse hubs.

- The '*New global governance model*' depicts the growing authority of multi-level and transnational governance actors – notably global philanthropies,

multinational enterprises, regional authorities, public-private partnerships, advocacy networks – in shaping R&I priorities.

- *'Emerging health challenges'* features increasing disease burden created by geopolitical instability, climate crisis and biodiversity loss. The accelerating climate crisis could bring One Health to the centre of health policies but implementation remains uneven. Consequently, pandemic preparedness and climate-health surveillance become central R&I topics. Similarly, rapid vaccine development and antimicrobial resistance (AMR) responses become urgent priorities.

The drivers and their possible development pathways towards 2050 are presented in detail in Annex I.

4. THE FOUR SCENARIOS

Each scenario is a combination of one dimension of the first core driver (Governance of science) and second core driver (Distribution). The other drivers' different development pathways toward 2050 are mapped to one of four scenarios. Figure 1 presents the four scenario sketches and their main features.

Figure 1 Scenario quadrant



The two 'extreme' quadrants diagonally are *Grand Project State* and *Frontier Archipelago*. They represent the sharpest imaginable contrast in what science even *looks like* institutionally. The other diagonal (*Platform Science* vs *Commons Network*) is essentially the debate about who owns the infrastructure of knowledge, which is arguably the most urgent question right now.

The section below presents the scenarios in detail and assesses their impacts on the future landscape of science, including both challenges and opportunities. In each scenario, we also identify stakeholders who would be most affected. We envision an optimal EU policy for each scenario and propose scenario-specific actions.

4.1. SCENARIO 1 - GRAND PROJECT STATE

Long-run geopolitical competition drives governments to consolidate scientific capacity around strategic priorities. Research is well funded but channelled: climate engineering, pandemic preparedness, space and energy dominate. CERN-style intergovernmental megaprojects are the standard model. Science is prestigious as a state function, but curiosity-driven research struggles to justify itself bureaucratically. Researchers navigate between national and bloc-level agendas. Framed as a global public good, science is state-captured rather than openly shared; its benefits are strategic first, global second.

Keywords: mission science, bloc competition, strategic priorities, slow but legitimate

By 2050, research and innovation are primarily funded and controlled by the public sector and organised through highly centralised institutions. Governments and regional blocs coordinate scientific agendas around long-term strategic priorities, making research a core instrument of economic resilience, security and geopolitical influence. Large, mission-oriented programmes dominate investment, focusing on AI, climate engineering, pandemic preparedness, deep-sea mining, space exploration, advanced energy systems and critical technologies. International 'CERN-style' research infrastructures have become the flagship model for scientific collaboration, though the degree to which they operate within unified versus competing geopolitical blocs depends on how global governance evolves. This is the scenario's central tension for science as a global public good: megascience infrastructure built for collective benefit is repurposed as a bloc-level strategic asset.

Scientific cooperation enters a two-speed regime: On the one hand, large international CERN-style projects can support collaboration on global problems such as pandemic preparedness and climate change mitigation; on the other, strategic technologies such as AI have become structured around regional alliances and state actors competing for technological leadership. The multilateral order has evolved into overlapping blocs with different standards, priorities and research partnerships. Governments pursue strategic

autonomy while maintaining selective cooperation on issues where mutual dependence remains unavoidable. Competition over critical minerals, space resources and strategic supply chains drives ambitious public investment in extraction technologies and next-generation manufacturing with a significant environmental cost. Moonshot programmes reinforce the state's role as the principal organiser of scientific progress.

Access to foundational technologies – including frontier AI, quantum computing, synthetic biology and digital twins – is concentrated within a limited number of publicly funded research infrastructures. Participation depends on alignment with strategic priorities, leaving many universities outside these flagship programmes. Research systems become increasingly hierarchical: a small group of institutions develops frontier science, while others focus on education, applied innovation and regional economic needs. Curiosity-driven research receives less support as funding increasingly favours predefined missions with measurable societal and geopolitical returns. Open-science norms erode as knowledge circulates within blocs, rather than across them, narrowing from global public goods to bloc public goods.

Security considerations shape nearly every aspect of research governance. Scientific capabilities are increasingly treated as strategic assets, and research funding is closely linked to national and bloc-level security objectives. AI accelerates discovery, optimises large-scale projects and supports public decision-making, enabling governments to respond rapidly to emerging crises. However, reliance on complex AI systems also creates new epistemic challenges, as many discoveries cannot be fully explained or independently verified. Despite this, visible successes in areas such as health, infrastructure and energy reinforce public confidence that state-directed science delivers tangible benefits.

The world also faces mounting environmental and health crises. Climate change, ecosystem degradation, biodiversity loss and geopolitical instability contribute to recurring disease outbreaks, including a major pandemic triggered by the crossing of ecological tipping points. Governments respond by expanding central coordination of health research and emergency preparedness, further reinforcing mission-oriented science. Yet climate change and pandemics were lessons for most everyone: begrudging cooperation through large international research institutions takes place as neutral fora of cooperation. While not every bloc cooperates with everyone else, public goods are still an avenue of cooperation, because leading in these domains brings prestige and technological advantage to the blocs that do so. Public trust in scientific institutions remains strong as citizens associate large-scale research programmes with jobs, infrastructure and crisis response, even as public debate becomes increasingly

fragmented. Science enjoys renewed prestige as a public institution, but its agenda is narrower, more strategic and less pluralistic than in previous decades.

Challenges for the EU's R&I strategy in this scenario

- National orientations and antagonisms (north-south divides, Italy/France vs Germany-style tensions) complicate coordination of R&I policy at the EU level.
- Directed, centralised research faces implementation challenges with centralisation processes, especially across different languages and legal and financial systems, but also in adopting novel technologies.
- Sustaining this level of ambition requires capital generation that centralised public funding alone may struggle to provide, especially given the current restriction on spending imposed on EU Member States.
- Public-private misalignment: when orchestration sits solely in the public domain, the EU risks missing opportunities generated in the AI private sector and misaligning its instruments, such as the Framework Programme, with actual end-user need.
- In the areas that the state focuses on less, the EU's innovation-deployment gap (the 'valley of death') persists, echoing Mario Draghi's diagnosis that innovation happens inside the EU, but deployment happens outside. Public orchestration in underfunded research and industrial areas misses the private-sector connection needed to translate research into scaled outcomes. In megaprojects where there is a significant public utility dimension, private capital is insufficiently mobilised alongside them.
- State-directed agendas threaten curiosity-driven research and pluralism; the lack of blue-sky research impacts research performance negatively in the long run, especially in the social sciences and humanities.
- Lack of diversity in technological choices risks locking in underperforming solutions and ultimately leads to less innovation, raising the question of whether the state actually delivers the benefits of science and innovation to citizens.
- AI-driven progress is expected to diverge by domain, accelerating science, technology, engineering and mathematics while leaving social sciences and humanities more human-led. This would strengthen the boundary between the human and technological domains.

- It leads to two opposing perspectives: one view holds that R&I becomes over-reliant on AI for breakthrough (rather than incremental) progress, with a persistent inability to explain outputs; a counter-view holds that by 2050 the EU will have found a working balance between AI-driven acceleration of discovery and human oversight of research direction and interpretation.
- Regional fragmentation of R&I performance worsens as centralised research and application efforts mean some regions are left behind by their own governments, while the EU is more preoccupied with excellence than with redistribution.

Opportunities presented by the scenario

- Assuming a functioning democracy, public funding implies stronger state accountability to citizens contingent on the existence of a real audit/accountability mechanism for that funding.
- Public trust in science remains comparatively high.
- Science is more explicitly oriented toward public welfare and benefit.
- A higher achievable level of ambition and convergence of means and political power can strengthen capacity to solve major challenges (e.g. cancer) and develop new markets (e.g. space industries).
- R&I funding is predictable and at scale, particularly for mission-oriented research, and supports excellence.
- Large-scale orchestrated research and deployment efforts on key technologies create 'European Champions' able to compete internationally, sustaining European competitiveness and a private sector ecosystem part of the supply chain, thus helping boost private sector R&I in these areas as a support for the 'champion'.
- A focus on megaprojects also creates incentives towards specialised education and the hiring of experts to contribute to the missions, creating a favourable ecosystem for brain gain.
- Because funding is public and centralised, benefits can in principle be redistributed more broadly across the population, though this depends on the EU remaining a redistributive system; under conditions of militarisation, this shifts from redistribution toward extraction of benefits by fewer actors.

Most-affected stakeholders

- Policymakers, who will need greater technical and multidisciplinary expertise
- The private sector and innovators
- Universities and research institutions
- Researchers impacted unevenly: some fields/domains win, others lose.

Optimal EU R&I policy in this scenario

- Integrate R&I policy with economic and trade agreements. In a bloc-based world, trade agreements govern access to critical materials, data and talent – three inputs R&I depends on. Address security pressures and the decline in international partnerships directly.
- Launch a workstream on epistemic and scientific validation under the Framework Programme. A mechanism to validate findings is needed precisely because AI-driven discovery is often unexplainable. Address the open question of how to do this validation without explainability/understanding AI driven processes/discoveries.
- Link industrial policy to deployment conditions via the ECF. This targeted, strategic policy would combine elements similar to the public long-range planning of China's five-year-plan model with the private-sector ambition typical of the US model. Address lack of competition and public-private coordination challenges.
- Improve research career and development conditions (linked to Horizon Pillar 1). Prioritise human-centred research. Build excellence in mission areas.
- Run EU-level missions in parallel with Member State task repartition and smart specialisation (addresses the national antagonism challenge), taking into account both the distribution of economic activity (georeturns) and of its benefits.
- Anchor the whole framework in EU values as principles.

Proposed EU R&I actions

- Base R&I policy on a survey or a study of existing capabilities so it builds on what can be scaled quickly.
- Extend policy coordination at the Member State level in order to align agendas and support better cohesion of EU and national policies.

- Reframe the MFF as long-term prosperity planning. Move it from a financial instrument to a strategic one, with a 'European seven-year plan' providing overarching direction and capacity planning linked to the CERN-style mission and mission-success milestones. This requires political momentum from national governments and a concrete roadmap, such as an action-oriented Draghi-style report, setting out the actions and benefits for all parties involved.

- Revive public procurement as a means of technological competitiveness: national or pan-European projects such as the Frontier AI Grand Challenge have a strong potential to support technology development and uptake.

- Ensure a successful ECF integrated with the Framework Programme. This requires clearly and distinctly defined roles for the Framework Programme versus the fund, successful delivery of large-scale Horizon Europe missions and their extension beyond 2030 with improved governance and funding as they grow. This connects to regional innovation valleys and CERN-style missions.

- Establish an Integrated International Partnership Strategy aligning the EU's international R&I cooperation with its trade and economic objectives, building on a clearly defined division of roles between the Framework Programme and the ECF and paving the way for integrated research, trade and economic agreements with third countries.

- Support regional EU-coordinated but regionally-led public-private initiatives such as the European Mission on Cities or the Oceans Mission, with regions specialising rather than competing against each other for the same capabilities. This action requires dedicated budget and decision-making authority for regional bodies, with the Committee of the Regions as a key actor, plus mission-oriented public-private partnerships that connect national industrial policy to the regional dimension.

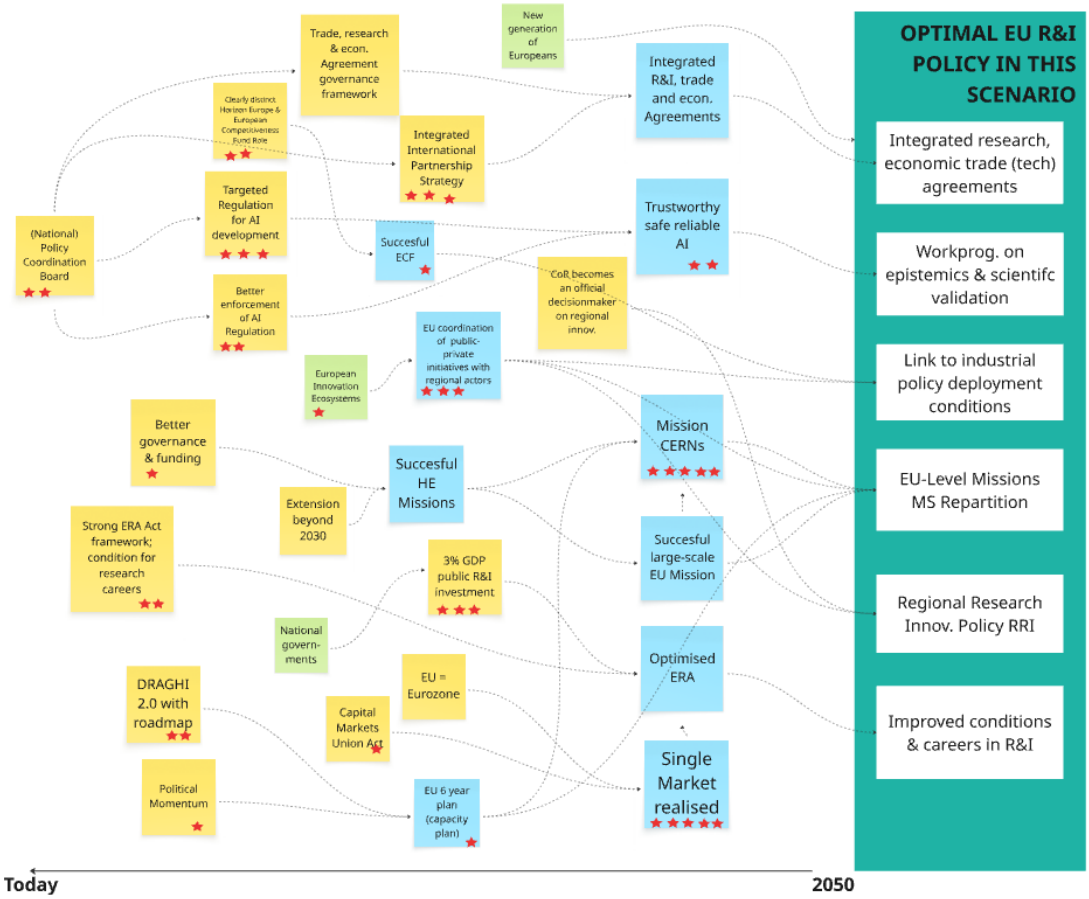
- Optimise the ERA Act to harmonise standards and improve researcher mobility and career conditions, which would require stronger centralised funding and portable pensions. Sub-milestones required for this include realising the EU Single Market (i.e. treating the EU as a functional eurozone) and the capital markets union, led by national governments.

- Direct 3% of GDP to public R&I investment as a concrete funding action underpinning improved research careers (including as researchers and founders in the private sector) and conditions. This would be more ambitious than the EU's existing 3% of GDP target, which combines public and private R&D spending;

isolating 3% for the public side alone represents a substantially higher public commitment.

- Develop a dedicated call in the 10th Framework Programme focusing on epistemics and metascience and the interaction of AI with research.
- Trustworthy and reliable AI can also feed directly into the above-proposed epistemics validation workstream. This action requires better implementation and enforcement of existing AI regulation, plus targeted regulation for AI development specifically.

Figure 2 Summary of the EU's R&I policy and actions in the 'Grand Project State' scenario



Note: Blue cards indicate key milestones, yellow cards key actions and green cards actors contributing to specific milestones. Red stars represent expert votes for robust actions (one star per vote).

4.2. SCENARIO 2 - PLATFORM SCIENCE

Two or three vertically integrated conglomerates, grown from the AI labs and cloud providers of the 2020s, now control the compute, the data and, increasingly, the publication infrastructure. Internal validation pipelines replace peer review. Most researchers are platform employees. Knowledge production is extraordinarily fast; openness and reproducibility are casualties. Regulators face a permanent asymmetry of information. Global public goods, from open knowledge to pandemic preparedness and climate research, depend largely on corporate discretion and philanthropy.

Keywords: proprietary infrastructure, IP-first, accountability deficit, speed without scrutiny

In 2050, research and innovation are dominated by a small number of powerful private conglomerates operating highly centralised infrastructures. Funding and control lie firmly in the hands of these actors, while research activities are organised through proprietary digital platforms. Science flows through closed ecosystems where access, participation and visibility are governed by platform rules. Public institutions still exist but operate at the margins, often dependent on private infrastructure. Speed, scale and capital define the system, while accountability mechanisms struggle to keep pace. Knowledge is increasingly managed as a club good: access is priced, licensed and conditional on platform membership.

Access to foundational technologies – AI, quantum computing, synthetic biology and digital twins –continues to expand, but remains highly unequal. The infrastructure required to develop and deploy these technologies is concentrated within major corporations and a handful of technologically advanced countries. As a result, participation in frontier research is restricted and limited to certain research areas only. Lower-income countries and underfunded institutions rely on licensed access to platforms, reinforcing dependency and limiting autonomous innovation capacity. Research priorities that matter most for these countries but promise little commercial return, such as neglected tropical diseases, local climate adaptation or food security, attract little platform investment.

Technological convergence accelerates this concentration. General-purpose AI acts as the central engine of discovery, integrating insights across domains and enabling rapid breakthroughs in biosynthesis, materials science and computational modelling. Biology, in turn, enhances computing through innovations such as neuromorphic chips. Dominant firms specialise in distinct technological niches, forming a competitive yet interdependent ecosystem. Control over general-purpose AI becomes the key strategic asset, intensifying private sector competition and reinforcing centralisation.

Governance structures reflect this shift. Traditional nation-state authority fragments as multinational enterprises, global philanthropies and public-private partnerships gain influence over research agendas. These actors establish private governance frameworks that operate alongside or beyond formal regulatory systems. Corporate interests increasingly shape priorities, often aligning with market opportunities rather than public needs. The provision of global public goods (e.g. pandemic preparedness, antimicrobial resistance, climate adaptation and biodiversity research) relies on the discretionary spending of a few philanthropic foundations and on corporate social responsibility programmes.

Geoeconomic competition further entrenches this landscape. States use trade dependencies and technological access as strategic tools, while full decoupling remains unfeasible due to deep interconnections. In some areas, escalating tensions lead to minimal multilateral agreements on critical standards to avoid systemic collapse. Meanwhile, reformed multilateral institutions incorporate emerging powers, but their influence is mediated through alliances with major technology firms, blurring the boundary between public and private authority.

Open science evolves into a hybrid model. Companies selectively promote openness to attract talent, build ecosystems and enhance reputation while tightly protecting high-value intellectual property. Publication becomes strategic rather than default. Knowledge circulates unevenly: foundational tools or datasets may be shared when this serves their ecosystem strategy but cutting-edge capabilities remain proprietary. This reinforces an IP-first model where control over data and algorithms determines influence, leading to very unequal access. Data on the global commons, such as climate observation and genomic, epidemiological and biodiversity data, is increasingly held in proprietary data lakes.

AI is deeply embedded in research work. It augments human capabilities, accelerates experimentation and improves research quality, but does not fully replace human judgement. Researchers increasingly act as supervisors of AI systems operating within platform environments. Regulation exists but primarily aims to sustain innovation and protect individual rights rather than constrain it. Dependence on proprietary AI tools further ties researchers to dominant platforms, consolidating the centralised, privately controlled structure of ‘Platform Science.’

Challenges for the EU's R&I strategy in this scenario

- Governments and the EU face the difficulty of remaining relevant in the global scientific agenda. Publicly funded research might be less efficient than private endeavours.
- Consequently, EU funding becomes less attractive for researchers, especially due to red tape. Public R&I investment shrinks drastically.
- Privately and publicly funded research have different objectives and outcomes.
- Diversity is another challenge, especially in the scope of research topics. Knowledge advancement is limited to the areas prioritised by big corporations. Research is limited by the large platforms, stifling certain research topics.
- State actors may fail to keep pace with technological advancements, affecting how they regulate research.
- Internally, there can be misalignment between the EU and its member states with regard to constitution of and incentives for R&I.
- Capability development is still a challenge, impacting competitiveness.
- The private sector's demands limit and weaken academic freedom.
- Data, including data critical for addressing shared global challenges such as climate, biodiversity and epidemiological data, becomes an expensive commodity that not everyone can access.
- Global public goods are systematically underprovided. Platforms invest where returns can be appropriated, so research on, for example, climate, global health and antimicrobial resistance depends on philanthropy and voluntary corporate commitments. Without predictable public financing, gaps persist, especially in times of crisis when rapid and open data sharing is most needed.
- The EU's ability to act as a global actor in science diplomacy weakens. Partner countries, particularly low- and middle-income countries (LMICs), may prefer direct deals with platforms that offer compute, data and tools, reducing the attractiveness of the Framework Programme.

Opportunities presented by the scenario

- Platform research will help researchers do research at scale with more powerful partnerships. AI and other foundational technologies will play a critical role in scaling up research.

- The scale and speed of platform science could accelerate breakthroughs on global challenges, such as vaccine development, climate modelling or new materials for the energy transition.
- The size of the EU Single Market gives it leverage to require platforms operating in Europe to contribute to global public goods, e.g. through open access to publicly co-funded results and data-sharing obligations during health emergencies.
- The EU's R&I funding can complement private sector funding if it chooses to support leading platforms owned by European firms. This may help reinforce the EU's competitiveness.
- There is opportunity for corporate responsibility to practise good research ethics with the EU acting as an oversight body. In this respect, the EU can create a robust corporate responsibility agenda.
- The EU can also retain and capitalise on data use and creation.

Most-affected stakeholders

- Society as a whole may benefit from faster scientific and technological progress, but could have less influence over research priorities and limited access to knowledge and technologies developed through privately controlled systems, including those serving as global public goods.
- Governments and policymakers may struggle to regulate rapidly evolving technologies and could lose influence over research priorities and critical infrastructure
- Researchers need to adapt their profile and skills as research becomes increasingly driven by commercial interests and market opportunities. They may feel pressure to focus on high-value or 'trendy' topics that attract private investment, potentially limiting academic freedom and reducing opportunities to pursue topics based on scientific curiosity or societal needs.
- LMICs, which depend on licensed access to platforms and whose priorities (e.g. neglected diseases, local climate adaptation) are least likely to attract private investment.
- Philanthropic organisations, which take on a growing share of the responsibility for setting agendas and funding global public goods.

Optimal EU R&I policy in this scenario

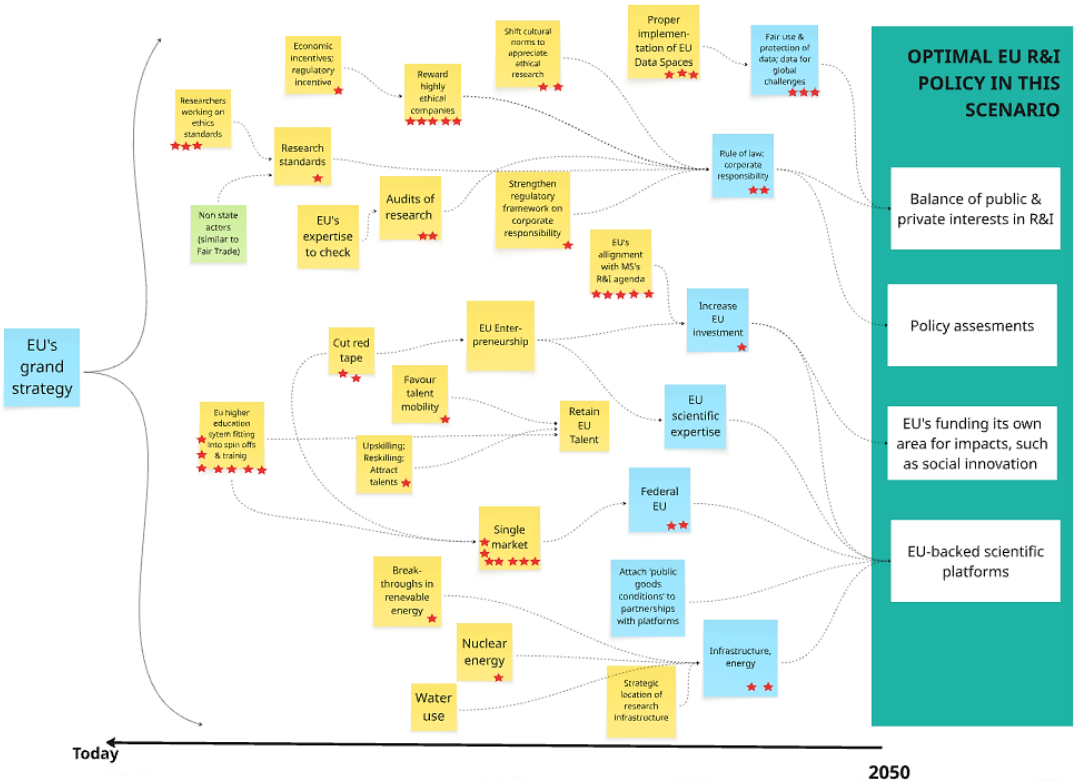
- The EU needs to play a leading role in balancing public and private interests in research institutions. For example, it can aim to have its own scientific platforms to support research that adheres to EU values and priority areas, which can in turn serve as European and global public goods. If the EU chooses to have a leading platform, it should have firms that participate in the global R&I ecosystem.
- The EU should act as a guardian of science as a global public good. It can leverage its Single Market, regulatory power and funding to ensure that knowledge critical for grand challenges (e.g. health, climate and biodiversity) remains accessible.
- EU R&I funding can target its own area for impact, such as social innovation.
- This scenario also requires the EU to better align its research policies with those of the Member States, taking a supportive rather than a steering role. One important step to achieve that goal is a more integrated ERA that acts as a platform on which privately led R&I can flourish, scale up and bring innovations to market across the Single Market rather than within national silos. A more coordinated approach would strengthen the European research system by enabling the EU and Member States to complement each other's priorities, resources and capabilities.
- The EU's R&I policy should combine the rule of law with corporate responsibility to ensure research ethics.

Proposed EU R&I actions

- The first action the EU needs to take is to further develop its Grand Strategy, which serves as guiding frameworks for policymakers. While competitiveness can be viewed as the current strategy, the EU should build its Grand Strategy with an eye toward the future so that its R&I policy and actions are planned through a longer vision, achieving broader goals.
- To ensure protection and fair use of data in this scenario, the EU could build and implement European data spaces that are accessible and efficient, including prescribing how different entities can use and access the data. Additionally, it could strengthen the implementation of EU laws and regulations to protect data, including data lakes. The EU could also ensure the interoperability of European data spaces with an international data commons, so that data critical for global challenges (e.g. climate, biodiversity, genomic and epidemiological data) remains accessible beyond platform ecosystems.

- For EU-based platform science to be possible, there should be a constitutional change that enables the EU to compete (Federal Europe style). For this to happen the EU must strengthen its Single Market today.
- To ensure that private-led research follows the rule of law on corporate responsibility, several alternative actions can be taken separately or collectively: i) ensuring that corporate responsibility is mandatory, ii) providing regulatory incentives including economic incentives to reward companies conducting highly ethical research, iii) setting research standards to ensure that research ethics are observed, iv) strengthening EU research audits that will nurture the culture of observing research ethics, and developing EU expertise to check if research ethics is being applied, and v) shifting cultural norms so that society values and favours companies with strong ethical research.
- For the EU to fund its own areas for impacts (such as social innovation), key actions include aligning it with the Member States' R&I agenda and supporting EU entrepreneurship through improving the business environment (cutting red tape).
- In this scenario, a key step the EU could take with regard to its R&I policy is to develop homegrown scientific expertise, which can be achieved through upskilling and reskilling, potentially attracting external talent. The EU could create an environment to favour talent mobility, retain EU talent and ensure that European universities are better resourced and Europe's higher education system fits into the university spinoff and training.
- The EU-based research platform needs to operate on reliable energy, water and infrastructure to ensure success. The core actions include having strategic locations of research infrastructure in terms of energy and resources and tapping into renewable sources.
- To safeguard global public goods, the EU could attach 'public goods conditions' to its R&I funding and partnerships with platforms. These could include open access to results co-funded by public money, and data-sharing clauses activated in health emergencies.

Figure 3 Summary of the EU's R&I policy and actions in the 'Platform Science' scenario



Note: Blue cards indicate key milestones, yellow cards key actions and green cards actors contributing to specific milestones. Red stars represent expert votes for robust actions (one star per vote).

4.3. SCENARIO 3 – COMMONS NETWORK

Open access mandates, federated data infrastructure and deliberate public investment in distributed capacity produce a genuinely pluralist ecosystem. Research priorities are partly set through civic deliberation and implemented at community level. Universities, civic labs, municipal research units and NGOs all contribute to a shared knowledge commons. The system is resilient and broadly trusted, but synthesis is hard, and meta-research and curation have become disciplines in their own right.

Keywords: open protocols, citizen science, methodological pluralism, coordination challenge

By 2050, research and innovation are predominantly publicly funded and organised through distributed networks rather than centralised institutions. Public investment supports open, decentralised infrastructures that enable universities, civic laboratories, municipal research units, NGOs and community organisations to contribute to shared knowledge production. Knowledge is managed as a global public good, with open access mandates and federated repositories providing the backbone of the system, while participatory processes shape research priorities. Citizen science operates at scale,

broadening involvement in setting research agendas, producing knowledge and fostering methodological pluralism.

The expansion of 'opening up science' has transformed who participates in research, ensuring that collective and societal priorities are addressed by R&I. Open-source practices extend beyond access to publications and datasets including patent data, encompassing broader participation in scientific activities and agenda-setting. Transdisciplinary collaboration is widespread, bringing together academic researchers, local communities, practitioners and underrepresented groups. Public institutions remain central funders and coordinators, and private actors continue to contribute expertise and resources within frameworks that preserve openness and shared ownership.

Multi-level governance structures have become more influential in coordinating research systems. AI assists international organisations, regional bodies and public agencies in allocating funding, monitoring collaboration and coordinating complex research networks. Following a major crisis of trust in proprietary AI systems during the 2030s, publicly developed and open-source AI platforms have become the preferred infrastructure for scientific collaboration. Dramatic reductions in computing costs, combined with accessible synthetic biology and AI tools, have democratised access to foundational technologies, allowing researchers across regions and institutions to participate more equally in global scientific activity.

International cooperation remains extensive despite an era marked by geoeconomic rivalry and strategic autonomy concerns. Governments seek to reduce vulnerabilities in critical sectors by developing decentralised research capacities and strengthening domestic capabilities, yet complete decoupling has proven impossible. Instead, a reformed multilateral order has emerged, combining regionalised approaches with security with sustained international cooperation in research and innovation. Established institutions have adapted to accommodate a wider range of non-Western actors and priorities, providing a minimum governance framework that preserves cross-border collaboration and scientific exchange.

Recurring climate shocks, pandemics and environmental pressures have reinforced the recognition that global challenges require collective responses and the importance of safeguarding global public goods. Public authorities, philanthropic organisations, NGOs and international partnerships increasingly pool resources to address health, climate and sustainability priorities. Knowledge sharing is widely regarded as a global public good. Scarcity of critical minerals and resource constraints have accelerated localised circular economies, embedding new battery technologies' longevity, reuse and recovery into research agendas and technological development. Advances in AI, biotechnology and

quantum technologies continue to reinforce one another. Innovation is guided by societal priorities rather than purely commercial incentives.

The Commons Network combines openness, diversity and public stewardship with distributed forms of coordination. It enables broad participation and strengthens societal trust in research, but the fragmentation of expertise and proliferation of actors create persistent challenges for integration, standardisation and collective decision-making. Meta-research, knowledge curation and coordination disciplines have therefore become essential components of the research ecosystem.

Challenges for the EU's R&I strategy in this scenario

- Multilateral and multi-level governance coordination will be grand challenges.
- With so many partners operating in a distributed network, there may be challenges to ensuring agility of governance and research capacity when needed.
- Further challenges for research governance in this scenario include developing mechanisms for multi-stakeholder agenda-setting, especially in a context where citizens and civil society might have a larger decision-making role.
- There are also challenges for collective decision-making, and synthesis has become a specialised field in its own right.
- This links to challenges in the allocation of funding and determining the right balance between different types of R&I (discovery, translational and development for example).
- The risk of fragmentation in a highly distributed research ecosystem may make it difficult to attract investment.
- Private-sector involvement is a challenge in this scenario, with a risk of a disconnect with this research ecosystem. The level of private-sector involvement, attracting investment and how to engage with them would be challenges.
- Providing open access to research infrastructures would be a challenge, and could produce tension between opening-up science and digital vulnerabilities, dual-use technologies and strategic autonomy. Cybersecurity would be critical.
- Measuring and evaluating research success and impact, standardising research quality and developing appropriate quality assurance mechanisms would be challenges in a highly diverse and distributed research network.

Opportunities presented by the scenario

- Increased citizen involvement in agenda-setting may help boost trust in R&I and a research agenda that is more aligned with societal goals.
- Increased societal involvement could lead to longer-term priority-setting and policymaking, contributing to a more resilient research ecosystem.
- Broader science-based increased data sharing, partnerships and collaboration may lead to better prediction and prevention of health and climate challenges.
- The research itself could be better, with an opportunity for higher levels of outputs and data. The increase in diversity of research actors envisaged in this scenario could lead to more diverse, multidisciplinary and innovative ideas.
- There would be opportunities for exploring and developing new innovation ecosystems with potential for the formation of new markets or a proliferation of SMEs.
- Augmented opportunities for local or regional economic growth could potentially reduce regional inequality.
- The division of material resources could be enhanced globally.
- Science as a global public good is embedded into the R&I ecosystem, with knowledge and data managed as a common good and open access and sharing prioritised. Increased public involvement in priority-setting could improve the alignment of R&I efforts with collective and societal goals.
- A more participatory research system could reinforce science diplomacy and soft power.

Most-affected stakeholders

- The public sector has a greater role and input.
- The private sector would be dependent on a public sector R&I agenda and ultimately has a smaller role in R&D. The exact impacts are likely uneven and vary across business size and sector.
- Researchers, especially through changing career trajectories and job market shifts.
- Citizens and society.
- The environment.

Optimal EU R&I policy in this scenario

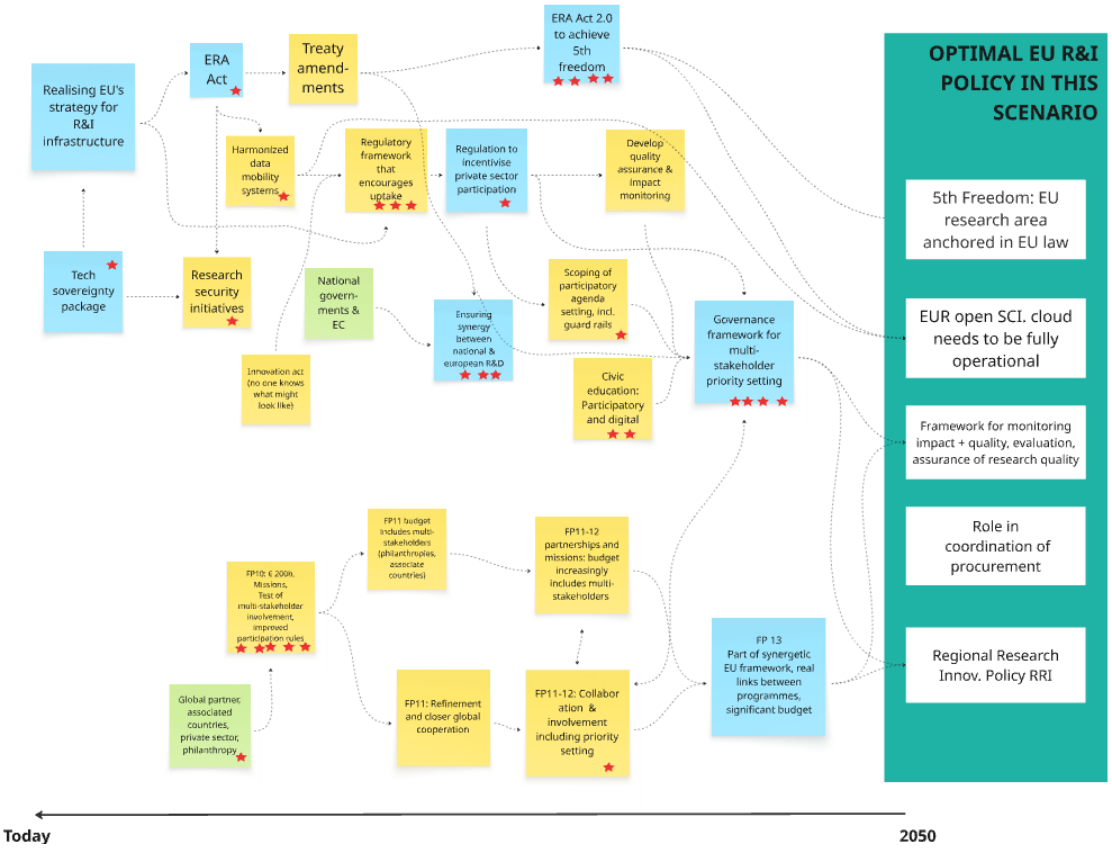
- Fully implementing the fifth freedom, with a European Research Area anchored in EU law and fully implemented.
- The European Open Science Cloud is fully operational.
- A framework for monitoring and evaluation of research impact and assurance of research quality.
- Established regional research and innovation policy.

Proposed EU R&I actions

- The EU's framework programmes would continue to play a major part in this scenario, underpinning a growing role of public funding for R&I and coordinating with partners and stakeholders. Successive Framework Programmes expand their budgets and opportunities for partnership, bringing together a wider range of stakeholders, including associated and partner countries, philanthropic organisations, the private sector and, increasingly, civil society. They also make greater use of Missions to address major societal challenges. With each iteration, these partners will have taken on a stronger role in agenda-setting and governance.
- The full implementation of existing or planned initiatives to realise the EU's strategy for R&I infrastructure and supporting open research, research collaboration and researcher mobility, and ultimately the full implementation of the fifth freedom. For example, the ERA Act and the Technology Sovereignty Package need to ensure harmonised data mobility systems and research security. In fact, the current ERA Act was deemed to fall short of fully achieving the 5th freedom for R&D in the context of such a diverse and distributed R&D ecosystem. An 'ERA Act 2.0' would fully enable this. It was acknowledged, however, that this in turn would require coordination between Member State and EU-level R&D policy and potential treaty changes to enact.
- Synergy is needed between local, national and EU R&D policy.
- Another key action is the development of regulatory frameworks that encourage uptake of innovation and incentivise private sector engagement with this distributed and publicly driven R&I ecosystem.
- The development of a governance framework for multi-stakeholder priority-setting is critical in this scenario. Several actions are needed to support this, including developing mechanisms for quality assurance and impact monitoring,

scoping different possible mechanisms for participatory agenda-setting, ensuring civic participation and determining the role of digital technologies and AI in supporting these processes.

Figure 4 Summary of the EU's R&I policy and actions in the 'Commons Network' scenario



Note: Blue cards indicate key milestones, yellow cards key actions and green cards actors contributing to specific milestones. Red stars represent expert votes for robust actions (one star per vote).

4.4. SCENARIO 4 – FRONTIER ARCHIPELAGO

Cheap compute, AI-assisted experimentation, low-cost biotech tools and decentralised funding (token-based, reputational, philanthropic) have made it possible for individuals or very small teams to conduct research previously requiring major institutions. The ecosystem is innovative but deeply fragmented: different communities operate with different standards of evidence, different publication norms, sometimes different ontologies of what counts as a finding. The challenge isn't producing knowledge –it's knowing what to trust. The provision of global public goods becomes increasingly difficult in this fragmented landscape.

Keywords: DAOs, epistemic fragmentation, garage biotech, high dynamism low coherence

By 2050, research has become radically decentralised. Cheap compute, AI-assisted experimentation, low-cost biotechnology and decentralised funding have enabled

startups, DAOs, independent laboratories and even individual researchers to perform work that once required major institutions. Venture capital, philanthropic networks and token-based funding rather than governments dominate the landscape. Science no longer revolves around large organisations but around thousands of competing research communities. The ecosystem is intensely merit-based: influence is earned through demonstrable breakthroughs, reputation and the ability to attract capital rather than institutional authority. Innovation is exceptionally fast, but quality standards differ across communities, open science has largely disappeared and regulation struggles to keep pace. The challenge is no longer generating discoveries – it's knowing which ones to trust.

Scientific collaboration increasingly resembles an archipelago of loosely connected islands. Informal alliances, reputation networks and capital-backed science cartels emerge as the dominant organisational model. These self-organised cliques control access to talent, specialised datasets, compute resources and investment, creating ecosystems built on trust rather than formal regulation. This fragmentation challenges the provision of global public goods in science and health.

Access to foundational technologies remains uneven. Sophisticated AI models and biotechnology tools are available to many smaller firms and independent laboratories, yet the most capable systems remain accessible only to those able to secure sufficient investment or develop them independently. Rather than intellectual property rights, competitive advantage rests on speed, secrecy, proprietary know-how and first-mover advantage. Biotechnology and AI increasingly interact, but their convergence remains opportunistic rather than coordinated, driven by commercial incentives instead of collective research agendas. Knowledge circulates selectively through self-organised networks and trusted collaborators, while openness survives only where it provides a competitive advantage.

Artificial intelligence becomes the dominant engine of discovery. Autonomous AI systems increasingly design experiments, generate hypotheses, conduct simulations and optimise research without continuous human supervision. Many independent laboratories evolve into AI-native research organisations where human researchers primarily validate strategic directions rather than perform scientific work themselves. As AI capabilities surpass human cognitive capacity across many research tasks, scientific productivity accelerates dramatically. At the same time, human expertise gradually erodes as researchers become increasingly dependent on AI-generated reasoning. Only a relatively small community retains the skills required to critically assess machine-generated discoveries, making trust, validation and interpretation the principal bottlenecks of scientific progress.

Global governance remains fragmented. Regional blocs pursue different research priorities and security concerns, creating distinct innovation ecosystems rather than a unified scientific community. Although regional blocs and private networks may develop solutions to specific challenges, their incentives and capabilities vary, leaving gaps in the provision of collective goods whose benefits extend beyond individual institutions, markets or geopolitical alliances. Global public goods increasingly depend on voluntary coalitions and philanthropic investment rather than predictable, collectively coordinated financing. Actors nevertheless establish limited multilateral agreements on minimum technical standards and interoperability, recognising that complete scientific decoupling would undermine innovation.

Competition for critical minerals intensifies, accelerating deep-sea mining, commercial resource extraction and eventually space mining, while occasional breakthroughs in alternative battery technologies periodically reshape global innovation races. Within Europe, research security increasingly reflects regional priorities rather than common international standards, reinforcing fragmented research ecosystems and competing technological spheres. Intra-European research communities increasingly align around competing regional networks, each developing distinct methods, standards of evidence and validation practices.

Challenges for the EU's R&I strategy in this scenario

- Major global players, such as the US, China, continue to dominate, while other countries stagnate and simply adopt emerging technologies as they appear. Not all countries need to form cartel-like alliances; some may instead become more insular and self-reliant.
- Cybersecurity and military security are increasingly outsourced to smaller, specialised actors.
- Social sciences and humanities risk becoming largely irrelevant under this scenario.
- Regulatory frameworks may struggle to keep pace, raising the question of whether 'agile regulation', continuously revised and updated, would need to become the norm.
- Without oversight of scientific conduct, there is no clear mechanism to ensure accountability and ethical responsibility in science, and no shared sense of purpose. Fragmentation risks producing a highly individualised society in which people focus primarily on personal gain rather than collective benefit. It is not being claimed that science currently drives this outcome, but under this scenario,

certain groups may increasingly exclude themselves from society if broader social norms reject this shift.

- Ethical standards are shifting rapidly. By 2050, there may be a significant erosion toward substantially lower ethical standards.
- Questions remain about how researcher performance would be assessed and whether publication output remains the primary KPI. Under this scenario, basic research could suffer, the traditional research mindset may erode, and researchers may increasingly be pushed toward entrepreneurial roles.
- Knowledge generated could become proprietary, remaining within the small firms funding the research rather than being made publicly accessible. The world may already be approaching a tipping point, with funding increasingly directed toward 'dual use' research, shifting Framework Programme priorities away from purely scientific goals toward competitiveness-driven objectives.
- A lack of collaboration could stall major infrastructure development, particularly for highly specialised, high-tech capabilities, e.g. Taiwan's advanced semiconductor lithography technology, which is exceptionally difficult to replicate due to its technical complexity.
- The potential climate impact is significant. Meaningful progress on climate change is a collective problem requiring coordinated, scaled solutions. But this scenario offers little incentive for any single actor to invest in it.
- Health risks and inequities would likely intensify under this scenario. Regions with limited access to technology experience extremely poor health outcomes and inadequate preparedness for a future health crisis. Vaccine development relies on private players, while governments lack the capacity to enforce market competition.

Opportunities presented by the scenario

- There would be a high innovation rate given the situational context.
- Innovation may become easier in the absence of frameworks such as General Data Protection Regulation (GDPR – not necessarily a positive outcome), creating a more open, low-barrier environment, akin to a 'buffet' of unrestricted experimentation that favours disruptive innovation.
- Regulatory frameworks could become a matter of negotiated agreement between coalitions of actors, rather than centrally imposed rules.

- Research could become increasingly securitised, benefiting whoever holds control, while posing a potential threat to others. This raises the question of how to safeguard dual-use technologies, for example, a scenario in which FP10-funded research is ultimately used to sell drones to China, suggesting a need for a more securitized global research environment.
- Research organisations would have a great deal of autonomy, though high levels of venture capital involvement could introduce corresponding pressure for high returns on investment.
- This scenario favours merit and performance; regardless of whether the outcomes are ultimately positive or negative, overall performance levels would be high.
- Some degree of coordination would still be necessary, as maintaining competitiveness and long-term survival requires a baseline level of security and cooperation among actors.
- Research is expected to become diversified, so even if some organisations fail, others are still likely to succeed, reducing systemic risk. This would not eliminate a replication crisis outright, but instead resemble a more competitive, 'survival of the fittest' dynamic among research actors. This assumes that the underlying knowledge being generated remains trustworthy.
- A rise in informal, garage-style innovation could emerge, with greater public access to available technology enabling more people to pursue independent, do-it-yourself innovation.

Most-affected stakeholders

- Researchers, facing greater autonomy but increased commercial pressure and challenges in validating AI-generated findings.
- Entrepreneurs, benefiting from easier innovation but facing intense competition and unequal access to resources.
- Private universities, with greater flexibility but also higher dependence on private funding and proprietary research.
- AI assistants, becoming central to discovery while raising concerns about reliability and accountability.
- Policymakers, who struggle to steer research towards the public good and ensure agile governance to safeguard research ethics and research quality.

- Citizens, with access to new technologies but also risks from unreliable science, privacy loss and inequality.

Optimal EU R&I policy in this scenario

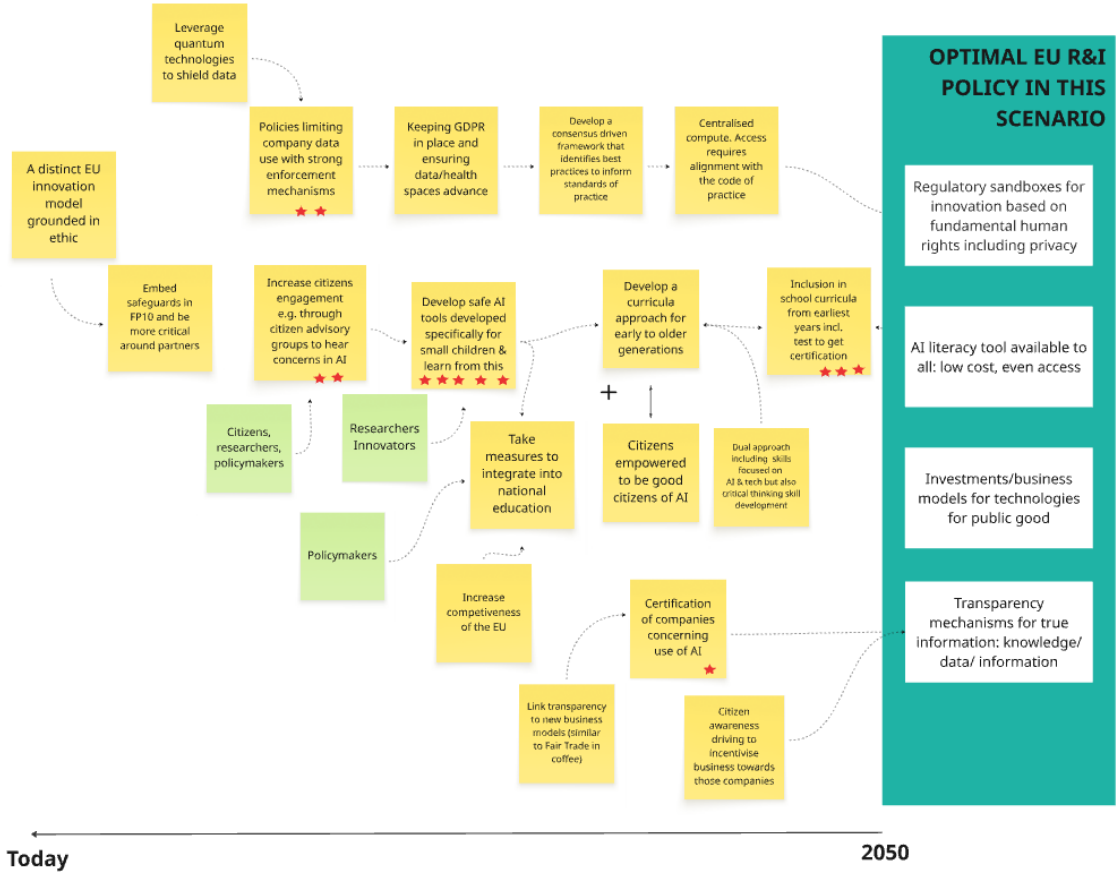
- Universal AI literacy tools. A freely accessible AI literacy that complements, rather than replaces, critical thinking-based curricula. Basic AI education should be designed appropriately for every stage of life, from primary education through to older generations.
- Transparency mechanisms to ensure discoveries and methods circulate beyond closed networks, so that trust in research findings does not depend solely on informal reputation.
- Targeted investment models for beneficial innovations. Investment and funding structures, including entry barriers or conditions, that channel capital toward technologies with positive societal goals such as health innovations.
- Rights-based regulatory sandboxes for innovation that are grounded in fundamental human rights and basic moral principles, including privacy protection.

Proposed EU R&I actions

- Regarding the AI curricula, the pathway to 2050 begins with citizen engagement and advisory structures designed to raise any concerns, particularly from marginalised groups and parents. Safe, child-specific AI tools would be developed and piloted, with lessons drawn from these early efforts feeding into broader curriculum development for all ages. This would take place alongside parallel work on policymaker tools and harmonised education standards across the EU. Together, these efforts would support the formal embedding of AI literacy in school curricula from the earliest years, including certification, ultimately culminating in universal, low-cost and easily accessible AI literacy tools by 2050.
- Concerning regulatory sandboxes underpinned by fundamental human rights, the pathway to 2050 begins today with safeguards embedded in FP10 licensing and a distinct, ethics-grounded EU model, deliberately charting a different course from the US. This would be strengthened by quantum-secured EU data and strict, genuinely enforced policies on corporate data use, while maintaining GDPR as a foundation that still allows progress within data spaces. Building on this, principled frameworks would be developed underpinned by identified best practices, requiring proof of compliance with codes of practice. Together, these steps would culminate in regulatory sandboxes for innovation, grounded in

human rights and moral principles by 2050. In terms of data and information, the pathway to 2050 begins today with citizen awareness driving pressure for greater transparency mechanisms for true knowledge. This would push new business models toward stronger transparency obligations, laying the groundwork for competency certification concerning the use of AI, a mechanism not yet applied. Together, these developments would culminate in transparency mechanisms capable of supporting effective knowledge transfer by 2050.

Figure 5 Summary of the EU's R&I policy and actions in the "Frontier Archipelago" scenario



Note: Blue cards indicate key milestones, yellow cards key actions and green cards actors contributing to specific milestones. Red stars represent expert votes for robust actions (one star per vote).

5. POLICY IMPLICATIONS

This foresight exercise provides policymakers with insights and ideas to prepare for multiple futures. The scenarios serve two purposes. Firstly, they help to prepare for uncertainty, acknowledging that multiple futures are possible and identifying early signals of change. Secondly, they clarify the actors and actions involved by presenting distinct futures and their potential impacts on the R&I landscape by 2050.

The scenarios paint very different landscapes for the governance of R&I and the scientific enterprise. The two diagonally opposed scenarios, *Grand Project State* and *Frontier Archipelago*, offer the starkest contrast in terms of how science could be organised institutionally. The other pair, *Platform Science* and *Commons Network*, focuses on who controls the infrastructure of knowledge. With varied implications on research and science, each scenario presents its own opportunities and challenges.

Should the EU have a preferred future to aim for? Experts raised this question during and after the foresight workshop. The answer largely depends on one's perspective. Through the authors' lens, a preferred future could incorporate a mix of elements from the four scenarios. This future could see strong coordination of scientific agendas that both tackle societal challenges and pave ways for frontier science and new markets. We also imagine a world in which research is conducted on a large scale thanks to partnerships at various levels, agreed technical standards and interoperability. In such a world, AI and foundational technologies would converge and accelerate discovery, optimising large-scale projects and supporting research oversight. AI augments human capabilities, accelerates experimentation and improves research quality, but does not fully replace human judgement. Start-ups, individual researchers, universities, civic laboratories, NGOs and community organisations will contribute both to identifying research topics and producing knowledge, thanks to open science and democratised access to foundational technologies. And, in our ideal future, the benefits of research are redistributed more widely across the population, including low- and middle-income countries.

The EU cannot fully achieve all of the above dimensions – there are always compromises to be made. While achieving that future is not easy, envisioning it helps us design our actions today. When making R&I policy choices and prioritising one dimension, policymakers should bear in mind that other dimensions and priorities also exist, and that it is best to preserve these to some extent.

The scenarios also shed light on the key stakeholders in the EU's future R&I policy. Policymakers, entrepreneurs, academia, research institutions, researchers, citizens and international partners will all be impacted and play a critical role in setting the R&I

agenda, conducting and monitoring research. One of the actions that remains relevant across all scenarios is the EU's use of multi-stakeholder partnerships in its R&I strategy, though the specific stakeholders and types of collaboration vary depending on the context of each scenario.

Our report concludes with a set of policy actions that the experts involved in the foresight exercise consider robust across multiple scenarios: actions likely to be effective in different future contexts, or at least unlikely to have negative consequences in any of them. These are the so-called 'robust actions' or 'no regret actions'. Table 1 summarises the robust actions that can be taken today, regardless of the future in 2050.

Table 1 Robust actions for EU R&I policy

Action	Grand Project State	Platform Science	Commons Network	Frontier Archipelago
Future-proofing current EU R&I instruments	X	X	X	
Completing the EU Single Market	X	X		
Aligning public R&I policies at multiple levels	X	X	X	
Engaging the private sector	X	X	X	X
Leveraging multi-stakeholder partnerships	X	X	X	X
Enhancing the governance of AI use in research	X		X	X
Ensuring oversight of research quality and impact	X	X	X	X
Securing the EU's research talent	X	X	X	X

Notes: 'X' indicates that the given action performs well in a scenario. A blank cell suggests that the action has no negative impact on that scenario.

5.1. FUTURE-PROOFING CURRENT EU R&I INSTRUMENTS

The complexity of future scenarios indicates the need for the EU to craft its Grand Strategy to navigate emerging contexts and world orders, and to plan its R&I policy and actions with a long-term vision. *Grand Project State* calls for the redefinition of the MFF as a means of planning long-term prosperity, with a 'European seven-year plan' providing overarching direction and capacity planning. In a world where state influence largely falls behind private power such as *Platform Science*, Europe's Grand Strategy serves as a guiding framework for policymakers to pursue temporal priorities such as competitiveness and security, while adhering to values and broader development goals.

The Framework Programme will continue to play a major role in delivering the Grand Strategy in state-led R&I landscapes such as *Grand Project State* and *Commons Network*, requiring close coordination with the ECF. Both scenarios highlight the need for the full utilisation of Missions to address societal challenges. Partnerships and Joint Undertakings would play an increasingly important role in pooling resources and attaining shared research and innovation goals. This is particularly relevant for the two public-led scenarios because public sources alone may struggle to provide the critical funding mass to do science at scale and tackle grand challenges, and the public-private misalignment would risk the EU's missed opportunities to leverage private expertise and capability. Even in private-led R&I worlds like *Platform Science* where EU funding (and public funding in general) becomes less attractive for researchers, European Partnerships and Joint Undertakings would create channels for the EU to pool resources with private partners to align agendas and attract talent.

Grand Project State and *Commons Network* also feature an ERA Act that is anchored in EU law and has been fully implemented. Such a robust ERA Act would contribute to harmonising standards, improving researcher mobility and career conditions, and realising the fifth freedom. In *Commons Network*, the context of a diverse and distributed R&D ecosystem may require an evolution toward 'ERA Act 2.0' to fully realise the fifth freedom for R&D. However, it was acknowledged that this would require coordination between Member States and EU-level R&I policy, as well as potential Treaty changes.

5.2. COMPLETING THE EU SINGLE MARKET

Realising the EU Single Market (i.e. treating the EU as a functional eurozone) is an important condition for stronger centralised R&I funding. This action is critical in a government-led R&I landscape (like *Grand Project State*) where a successful Single Market helps to harmonise standards, improve researcher mobility and enhance career conditions. It is also essential in a world where science is led by private players (*Platform Science*) where a fully functioning Single Market would be a pre-requisite for

constitutional change that would enable the EU to compete and establish its own platform science, following a 'Federal Europe' approach. Building on the political commitment expressed in the One Europe, One Market roadmap, the EU should now turn ambition into concrete implementation measures and deliver a fully functioning Single Market by 2027.

5.3. ALIGNING R&I POLICIES AT MULTIPLE LEVELS

The EU should enhance the synergies of R&I policy at the EU, national, regional and local levels. This is an important step in aligning agendas and supporting the cohesion of EU and national policies (Grand Project State and Commons Network), as well as mobilising a critical and coherent mass of funding for the EU to invest in its own areas for impacts (such as social innovation) in a world where R&I is centralised in private platforms (Platform Science). In Grand Project State, EU-coordinated but regionally led initiatives, such as the European Mission on Cities, or the Oceans Mission, could enable regions to specialise rather than compete against each other for the same capabilities. This action requires a dedicated budget and decision-making authority for regional bodies, with the Committee of the Regions playing a key role.

5.4. ENGAGING THE PRIVATE SECTOR

Alignment between public and private R&I policies and funding is critical in all the scenarios. Although the four futures differ in whether public or private players orchestrate R&I by 2050, neither sector is necessarily less important in a given scenario. In fact, all the scenarios require close coordination to mobilise critical funding, pool expertise and ensure that science serves the public good.

The form of alignment varies across scenarios. In *Grand Project State*, public support through channels such as public procurement could help bridge the innovation-deployment gap (the 'valley of death') in areas receiving less state attention. *Commons Network* would face challenges in attracting private investment in a distributed research ecosystem and require new innovation ecosystems to foster new markets and a proliferation of SMEs. In *Platform Science*, the EU could engage firms in European scientific platforms that are aligned with EU values and priorities (such as social innovation) to deliver public value. Key actions include supporting EU entrepreneurship by reducing administrative burdens and deepening the Single Market and capital markets. Similarly, in *Frontier Archipelago*, where social sciences risk becoming marginalised, the EU could develop targeted investment models that offer favourable entry conditions and channel capital towards technologies with positive societal goals.

5.5. LEVERAGING MULTI-STAKEHOLDER PARTNERSHIPS

Strengthening the EU's partnerships with multiple stakeholders plays a significant role in all the scenarios. In public-led R&I environments such as *Grand Project State* and *Commons Network*, this action suggests the EU should establish partnerships with a variety of stakeholders, including associate and partner countries, philanthropic organisations, the private sector and eventually civil society. Integrating the EU's R&I policy with its trade and economic agenda (e.g. aligning Framework Programmes and the Competitiveness Fund), increasing the budget for Joint Undertakings and partnerships under the Framework Programmes and strengthening stakeholder engagement in R&I agenda setting and governance are critical in these scenarios.

In private-led R&I worlds, coordination between the EU and private actors is of the utmost importance. For instance, in *Platform Science*, where multinational enterprises and global philanthropies gain influence over research agendas, the EU must promote public-private research partnerships to adhere to EU values and priorities, which can serve as public goods. In *Frontier Archipelago,* where regulatory frameworks may struggle to ensure ethical standards and assess knowledge and researcher performance, the EU and governments could remain relevant by negotiating agreements with a coalitions of actors, rather than imposing rules centrally.

5.6. ENHANCING THE GOVERNANCE OF AI USE IN RESEARCH

AI plays a core role in all four scenarios, impacting not only the way we do science, but also how we validate research findings, allocate funding and monitor complex research networks. Scenarios where states play a central role in regulating the use of AI such as *Grand Project State* particularly need better implementation and enforcement of existing AI regulations and regulations targeting AI development. In worlds of open-source AI platforms and low computing costs (such as *Commons Network* and *Frontier Archipelago*), R&I policy should aim to ensure the equal participation of researchers from different regions and institutions in global scientific activity. AI literacy plays a key role here. It should be freely accessible and complement rather than replace critical thinking-based curricula. Basic AI education should be designed for every stage of life. Data is another core building block. Principled frameworks built on GDPR would be essential for developing data spaces and protect identities to enable the effective use of AI in research and governance.

5.7. ENSURING THE OVERSIGHT OF RESEARCH QUALITY AND IMPACT

All the scenarios call for enhanced oversight of scientific research, both because foundational technologies (AI, quantum, biotech) could drastically accelerate the research process in an unprecedented way, and because research could be organised in alternative ways (privately controlled and/or distributed) by 2050. This challenges the monitoring and validation of data, knowledge and research findings. *Grand Project State* and *Commons Network* highlight the need for dedicated calls in the Framework Programme on epistemics, metascience, the standardisation of research quality and the interaction of AI with research. *Platform Science* requires the EU to establish research standards and provide companies with regulatory or financial incentives to conduct ethical research. Both *Platform Science* and *Frontier Archipelago* highlight the need to shift cultural norms to encourage business models to embrace strong research transparency and research ethics more broadly.

5.8. SECURING THE EU'S RESEARCH TALENT

All the scenarios would have significant impact on researchers and require the EU's actions to nurture and maintain its pool of research talents. In *Grand Project State*, researchers will be affected unevenly, with some fields and disciplines benefiting (the 'mission' areas), while others would lose out. In *Commons Network*, researchers will face changing career trajectories and shifts in the job market. In *Platform Science* and *Frontier Archipelago*, basic research could suffer, and research in general could become increasingly commercialised and entrepreneurial. To create a favourable ecosystem for EU brain gain, EU actions could include improving research career and development conditions (linked to Horizon Europe Pillar 1), prioritising human-centred research (including offering AI literacy tools to complement, rather than replace, critical thinking-based curricula), strengthening resources for universities, and aligning Europe's higher education systems with university spin-offs.

ANNEX I: DRIVERS OF CHANGE

Driver 1 'Access to foundational technologies'	
Dominant pathway – **Steady advancement, unequal access.** AI, quantum computing, synthetic biology and digital twins advance rapidly, but the infrastructure to develop and run them remains concentrated in wealthy countries and large corporations.	*Impacts on R&I:* • Most researchers benefit from incremental improvements, but cutting-edge capabilities remain out of reach for smaller institutions and LMIC researchers. • R&I funding increasingly flows toward institutions that can afford the infrastructure, widening global R&I inequalities.
Deviant pathway – **Democratised foundational technologies.** Computing costs fall dramatically, open-source AI matures and synthetic biology tools become widely affordable, enabling broad researcher access regardless of geography.	• Foundational technologies become accessible to a much broader range of researchers, regardless of institutional affiliation or geography. • A wider pool of researchers can conduct sophisticated experiments, diversifying the questions science asks and the problems it prioritises.
Disruptive pathway – **Catastrophic event triggered by foundational technologies.** An uncontrolled AI system, a synthetic biology accident or a cyberattack on critical infrastructure triggers severe international restrictions on foundational technology development.	• Public backlash erodes trust in science broadly, making it harder to secure funding and societal support for R&I.
Driver 2 'Convergence of foundational technologies'	
Dominant pathway – **Biotechnologies, AI and quantum computing are mutually reinforcing**, with AI enabling discoveries and massive progress in biosynthesis while biology provides solutions to AI (neuromorphic chips).	*Impacts on R&I:* • Mutual reinforcement of AI and biotechnology can accelerate discovery and open entirely new cross-disciplinary research fronts.
Deviant pathway – **Biotechnologies, AI and quantum computing work in parallel**, with some knowledge exchanges, but if one collapses for lack of innovation, it does not affect the other.	• Convergence raises the value of interdisciplinary R&I capacity spanning computation and the life sciences.
Disruptive pathway – **Biotech leap.** AI hits a plateau; biotechnologies make massive progress in human enhancement and bioengineering for economic uses & climate change adaptation.	• Over-reliance on a single technology trajectory creates research risk if AI progress plateaus. • Biology-inspired computing (e.g. neuromorphic chips) could redirect R&I priorities in hardware and AI.
Driver 3 'Open science and R&I'	
Dominant pathway – **Open science remains a side approach**, most research is done from labs and the main publishers maintain a monopoly on excellent science.	*Impacts on R&I:* • Persistent publisher monopolies keep excellent science behind paywalls, constraining open access to R&I outputs and reproducibility.

Deviant pathway – **Open source becomes a powerful paradigm** for alternate cyber systems (as the EU is developing) or crowd-based competition to incumbents (open-weight AI models).	• Open-source becomes a powerful R&I paradigm, enabling alternative EU cyber-systems and crowd-based competition with incumbents such as open-weight AI models.
Disruptive pathway – **Open source becomes the dominant paradigm** for science, proliferating dangerous innovations	• Dominant open-source science accelerates diffusion but raises biosecurity and dual-use risks by proliferating dangerous innovations.
Driver 4 'AI in work'	
Dominant pathway – **AI augments work.** AI replaces workers in repetitive, well-defined tasks while humans retain higher-order and creative responsibilities.	*Impacts on R&I:* • Upskilling and reskilling become essential, with institutions investing heavily in training as jobs require higher education and soft skills.
Deviant pathway – **AI replaces work**. AI takes on complex, intellectual and creative tasks, dramatically accelerating research output.	• AI accelerates the speed of doing research • AI systems trained on existing knowledge risk reproducing dominant paradigms and making genuine scientific breakthroughs rarer.
Disruptive pathway – **AI-induced epistemic crisis**. AI produces knowledge so fast and at such scale that humans can no longer validate, interpret or trust scientific outputs, triggering a collapse in the credibility of science.	• Peer review systems become overwhelmed or obsolete, eroding public and institutional trust in science. • Public trust in science erodes, with political consequences for R&I funding. • New meta-research disciplines emerge to curate, validate and interpret AI-generated knowledge.
Driver 5 'Transformation of the multilateral order'	
Dominant pathway – **Rise of competing multilateral frameworks and regional/bloc cooperation.** Alternative frameworks (e.g. BRICS) grow separately from Western-shaped organisations, whose global influence declines. As a result, knowledge and technology shifts eastward and southward.	*Impacts on R&I:* • R&I priorities become increasingly regionalised and competitive. • Risk of duplicating research infrastructures. • Western R&I programmes must accommodate diverse methodologies to attract Global South partners. Brain drain: researchers move towards more competitive East/South-aligned R&I programmes.
Deviant pathway – **Reform of Western-shaped organisations.** Formerly Western-dominated organisations are reformed to reflect the interests of rising powers in the Global East and South (e.g. E7).	• R&I frameworks better reflect Global South interests, with local knowledge and grassroots innovation gaining recognition. • Technology transfers become binding and open-source science is strengthened for public-good cases.
Deviant pathway – **Western organisations retain dominance.** East and South become disunited; many Global South countries favour a return to Western-led multilateral frameworks	• EU retains standard-setting power in R&I governance • Global North maintains influence within international frameworks. • Western R&I programmes benefit from expanded talent and research capacity.

	• IP frameworks continue to benefit EU and Western commercial R&I interests.
Disruptive pathway – **Forced convergence into unified global governance.** A major global crisis forces a temporary overhaul and convergence of multilateral frameworks into a far more unified global governance model.	• The new governance model fundamentally resets norms around open science, data sharing and IP rights. • Open science and open-source data become binding norms, with unprecedented overhaul of intellectual property rules.
Driver 6 'Supply and demand for critical minerals'	
Dominant pathway – **Growing geopolitical competition for critical minerals.** Transition to renewables and rising demand for digital technologies increase demand for critical minerals, with China dominating supply chains.	***Impacts on R&I:*** • Innovation opportunities emerge in non-critical mineral-based battery technologies. • Resource scarcity impacts R&I in terms of availability of raw materials and cost.
Deviant pathway – **Rapid acceleration toward a circular economy.** Sovereignty concerns drive regulatory efforts prioritising longevity and resource recovery, transitioning economies from single-use manufacturing toward service-based models.	• High innovation potential for recycling technologies, novel materials and behavioural science. • Public funding for R&I directed toward circular economy and sustainability solutions.
Disruptive pathway – **Deep-sea mining.** Rapid and unregulated expansion of deep-sea mining produces critical minerals but entails significant environmental cost and intensifies geopolitical competition in this sector.	• Extraction technology R&I receives increased investment, reducing pressure on mineral supply for research. • Increasing dominance of privatised R&D as commercial interests drive deep-sea mining expansion.
Disruptive pathway – **Game-changing battery technology eliminates mineral dependency.** Sudden innovation in battery technology (e.g. sodium-ion) dramatically reduces reliance on critical minerals, triggering significant geopolitical power shifts.	• R&I agendas shift rapidly toward new technology and innovation pipelines for implementation.
Driver 7 'Securitisation of non-military affairs'	
Dominant pathway – **Comprehensive security state.** Areas previously considered standard policy – public health, tech, regulation – become framed as security matters, with governments embedding security logic across everyday policy areas.	***Impacts on R&I:*** • R&I priorities are redirected toward strategic interests, narrowing scope and increasing top-down control over research agendas. • Security screenings for international partnerships become the norm, favouring geopolitical alignment over scientific merit.
Deviant pathway – **Regionalised securitisation.** Securitisation prevails but differs between regions (e.g. Europe securitises migration; the US securitises AI), leading to incoordination and a fragmented global governance framework.	• Researchers seek jurisdictions where their field is least securitised, leading to geographically distinct R&I hubs per field. • International R&I programmes like the Framework Programme lose relevance as conflicting member priorities drive nationalisation of R&I schemes.

Deviant pathway – **De-securitisation and return to liberal internationalism.** A geopolitical détente leads to reintegration of multilateral frameworks, gradually curbing the securitisation trend.	• R&I collaboration rebounds in areas previously securitised like AI, quantum computing and biotech. • Cross-border cooperation is facilitated as security screenings ease and visa regimes relax.
Disruptive pathway – **Militarisation of governance.** A severe security crisis leads to prolonged emergency powers, fusion of civil and military institutions and proliferation of surveillance infrastructure.	• R&I funding becomes embedded within the government executive, losing autonomy and becoming highly politicised toward short-term government interests. • Universities lose autonomy and researchers effectively become civil servants under state control.
Driver 8 'Geoeconomic competition and strategic dependency'	
Dominant pathway – **Instrumentalisation of trade and economic dependencies.** Strategic autonomy drives policy as geoeconomic dependencies become primary tools of geopolitical confrontation, even as full decoupling remains impossible.	*Impacts on R&I:* • R&I agendas prioritised toward strategic autonomy: critical raw materials, domestic semiconductors, energy storage and pharmaceutical supply chains. • Justification for public R&I funding increasingly requires demonstration of relevance to strategic objectives.
Deviant pathway – **Multilateral rapprochement on minimum global rules.** Recognition of a lose-lose scenario in geoeconomic confrontation leads to multilateral minimum standards in critical areas.	• Possible ring-fencing of fundamental science to protect it from geopolitical instrumentalisation, agreed multilaterally. • CERN-style multilateral R&I funding for inherently global areas is facilitated.
Disruptive pathway – **Forced immediate decoupling.** A sudden geopolitical crisis leads to forced immediate decoupling of otherwise globalised systems – telecommunications, energy, pharmaceutical supply chains.	• Emergency nationalisation or state control of critical R&I-relevant industries to prevent technology transfers. • Sudden moonshot logic sees states invest heavily and rapidly to rebuild domestic capacities lost through decoupling.
Driver 9 'Changing lifestyles'	
Dominant pathway – **Growth in services, experiences and digital consumption.** Lifestyle trends continue in their current direction, with growth in services and digital technologies; protein-rich diets increase globally while sustainability trends do not substantially alter overall consumption.	*Impacts on R&I:* • Private sector R&I pulled toward high-consumption sectors, directing innovation away from social good. • Pressures on resources implicate R&I and direct it toward material efficiency and resource management.
Deviant pathway – **Two-tier consumption driven by inequality.** Extreme wealth drives ultra-high consumption lifestyles while inflation, austerity and job insecurity limits consumption for the lower-income majority.	• Private sector R&I pulled toward luxury and high-consumption sectors, widening the gap between research for the wealthy and for the majority.
Deviant pathway – **Value shift to a post-consumer economy.** Climate anxiety, regulatory	• Behavioural science and circular economy R&I increase.

intervention and social justice considerations reduce consumption in high-income countries, shifting patterns toward fairer, circular and localised economies.	• Research agendas shift toward sustainability, including alternative proteins, repairability and recycling technologies.
Driver 10 'Platformisation of public discourse'	
Dominant pathway – **VLOPs become the hubs of public discourse**, with algorithmic personalisation entrenching echo chambers, proliferating disinformation and decreasing institutional trust.	*Impacts on R&I:* • Public trust in expert-driven science declines, making science communication an R&I necessity. • R&I funding into disinformation, algorithmic governance and digital platforms grows.
Deviant pathway – **Successful regulation of VLOPs.** VLOPs become successfully regulated through packages like the EU's DSA/DMA, minimising social harm while maintaining their role as public discourse hubs.	• Public trust in science is maintained at levels sufficient for effective public health interventions. • EU positions itself as a global standard-setter in digital platform regulation, proliferating EU-led R&I in this area.
Disruptive pathway – **Epistemic fragmentation undermines democratic governance.** Algorithm-driven community fragmentation makes factual consensus practically unachievable, breaking down the shared epistemic foundations of democratic governance.	• The social contract underpinning R&I breaks down, with elected officials adopting ever more short-term perspectives on R&I funding. • Achieving agreement on R&I outcomes leads to paralysis in advancing and implementing science-based improvements.
Driver 11 'New global governance model'	
Dominant pathway – **Expanding authority of multi-level and transnational governance actors.** Global philanthropies, multinational enterprises, regional authorities, public-private partnerships, advocacy networks grow in influence, shaping policy agendas and R&I priorities through private-to-private governance frameworks.	*Impacts on R&I:* • Private organisations and public hybrid actors take an increasingly larger share of global R&I funding, with research gravitating toward private sector interests. • Accountability deficits proliferate unless regulation compels transparency in R&I funding.
Deviant pathway – **Re-centralisation of nation-state authority.** Backlash against non-state actors leads to reassertion of state governance, e.g. curbing influence of transnational commercial practices that bypass national legal systems ('lex mercatoria').	• Public research institutions and international organisations regain primary agenda-setting powers over R&I. • Sustained long-term investment in blue-sky discovery research with little commercial value is restored.
Disruptive pathway – **AI-mediated governance.** Decision-making shifts towards AI-driven centralised systems for considerations of expediency and convenience, e.g. AI-based tax accounting, predictive policing, dispute settlements, policy brainstorming.	• R&I could be more democratised through open access to centralised information, or more restricted, depending on how top-down AI governance becomes. • Non-traditional sources of R&I funding, such as crowdfunding and other fintech advancements, proliferate.
Driver 12 'Emerging health challenges created by geopolitical instability, climate crisis and biodiversity loss'	
Dominant pathway – **Increasing disease burden with uneven One Health integration.** Climate disruption increases zoonotic disease	*Impacts on R&I:* • Pandemic preparedness and climate-health surveillance become central R&I topics.

outbreaks; health systems gradually integrate One Health and climate-health approaches, but implementation remains uneven.	• Financing gaps and geopolitical fragmentation constrain R&I cooperation, particularly in LMICs.
Deviant pathway – **Global consensus drives One Health to the forefront.** Accelerating climate crisis brings One Health to the centre of health policies, with coordinated global funding and targeted action.	• Funding available for surveillance, pandemic preparedness and vaccine development. • Vaccine development and R&I processes become increasingly efficient in response to emerging threats.
Disruptive pathway – **Multiple ecological tipping points trigger a new pandemic.** Simultaneous ecological tipping points – biodiversity collapse, Arctic thaw, crop failures – contribute to a highly transmissible zoonotic pathogen with severe global consequences.	• Rapid vaccine development and AMR responses become urgent priorities. • Innovation driven by health security concerns, but limited technology transfer between north and south persists.



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