

# CFI Working Paper

## Action Roadmaps for More Resilient Research and Innovation Futures

Strategic Pathways to Foresight-Driven and Sustainable R&I Policies in FP10

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## Executive Summary



The **CFI Working Paper: Action Roadmaps for More Resilient Research and Innovation Futures** provides a forward-looking blueprint for shaping Europe's next Research and Innovation (R&I) Framework Programme (FP10). Through comprehensive foresight methodologies, stakeholder engagement, and insights from multiple visions, the paper addresses the urgent need for resilience, inclusivity, and sustainability in an evolving global landscape.

At the core are five transformative visions: *Fractured Futures*, highlighting the challenges of regional disparities and fragmented progress; *Converging Horizons*, envisioning collaborative global growth and equitable innovation; *Align, Act, Accelerate*, focusing on Horizon Europe's evolution; *Manufacturing R&I for Competitiveness*, addressing strategic autonomy through advanced manufacturing; and *Inclusive, Agile, and Impact-Driven R&I*, championing equitable participation and interdisciplinary excellence. Each vision is underpinned by actionable roadmaps with strategic, tactical, and operational layers designed to ensure relevance across diverse futures.

The paper identifies cross-cutting R&I priorities, including the integration of **circular economy principles**, the development of **decentralised energy systems**, and fostering **inclusive innovation ecosystems**. Specific policy options, such as strengthening **regional and global green tech hubs**, advancing AI for sustainability, and embedding **dual-use technologies**, align innovation with societal challenges like climate adaptation, biodiversity, and migration resilience. Wild Cards and Weak Signals analyses provide additional foresight into low-probability, high-impact events, informing the development of transformative policies.

Emerging technologies such as fusion reactors, smart grid systems, and blockchain governance platforms bridge societal needs with advanced innovation. Disruptive innovations like adaptive city designs and citizen-led governance initiatives further enhance resilience, inclusivity, and environmental restoration.

Key recommendations include a **€220 billion budget expansion for FP10**, streamlined governance, and enhanced public-private partnerships. These measures aim to align R&I efforts with EU priorities, promote talent pipelines, and build global alliances for shared sustainability goals.

This Working Paper invites R&I policymakers, Research and Technology Organisations (RTOs), Research Performing Organisations (RPOs), funding bodies, industry leaders, and civil society actors to collaborate on these strategic pathways, ensuring Europe's innovation ecosystem remains globally competitive, resilient, and inclusive.

## Introduction

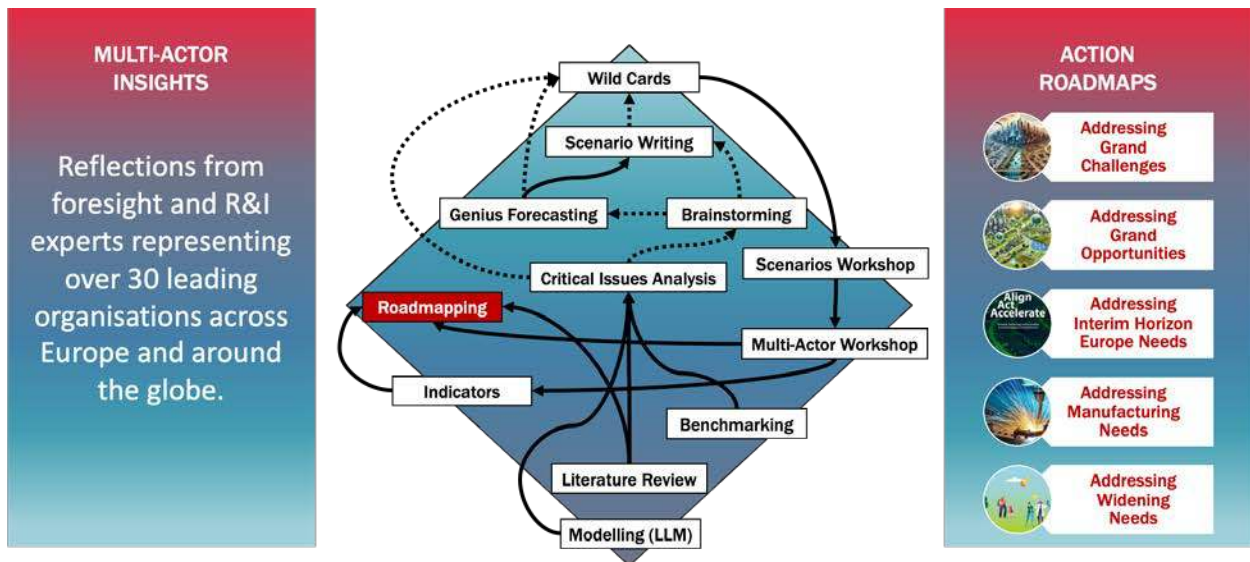
The forthcoming European Union Framework Programme for Research and Innovation (FP10) represents a pivotal opportunity to solidify Europe's position as a global leader in sustainable, inclusive, and transformative innovation. Building on the foundation laid by the earlier publication **Frontier Visions for More Resilient Research and Innovation Futures: Strategic Pathways for a Cohesive and Sustainable EU in FP10** (Popper & Towpik, 2024), this Working Paper advances the discussion with expanded insights drawn from stakeholder feedback during Brussels workshops. Notably, six new dimensions – Geopolitics and Power, Defence and Security, Techno-Economic, Socio-Cultural, Spatial, and R&I Policy – have been integrated into the **Frontier Visions**, enriching the scope of the analysis and ensuring its alignment with Europe's evolving R&I landscape.

This framework underpins the present paper, **Action Roadmaps for More Resilient Research and Innovation Futures: Strategic Pathways to Foresight-Driven and Sustainable R&I Policies in FP10**, which employs rigorous methodologies, including systematic literature reviews, advanced foresight tools, and multi-stakeholder engagement. Guided by evidence-based analysis and expert input, the process developed five complementary Action Roadmaps strategically addressing Europe's diverse R&I challenges. These roadmaps aim to foster resilience, sustainability, and competitiveness in a dynamic global context. To ensure actionable outcomes, the methodology incorporates the "3R" Methodological Frame (Velasco, 2017; Velasco et al., 2021):

- **Reposition:** The process immersed key stakeholders in transformative scenarios – such as *Fractured Futures* and *Converging Horizons* – to stimulate creativity and ensure the development of robust and innovative R&I strategies. This repositioning allowed stakeholders to explore a range of hypothetical contexts, fostering adaptability to both fragmented and collaborative futures while addressing EU's challenges and opportunities.
- **Representation:** Inclusivity was a cornerstone, achieved through engagement with over 50 experts from academia, industry, policy, and civil society. Activities such as the workshops on Technology Foresight, a multi-RTO Technology Foresight exercise on FP10, and focus groups organised by a Task Force aimed to share best practices in Foresight ensured diverse perspectives and multi-disciplinary insights. This approach enriched the thematic scope of the recommendations, grounding them in the realities of Europe's R&I ecosystem.
- **Resolution:** Insights from foresight workshops and desk research were systematically organised into the Action Roadmaps, addressing ten key aspects of sustainable innovation governance: Momentum, Foresight, Resources, Mobilisation, Aptitude, Attitude, Catalysts, Fosterers, Transformation, and Sustainability. This approach ensured high-quality, evidence-based policy advice that is actionable, credible, and aligned with EU priorities.

The following sections invite readers to explore the two contrasting **Frontier Visions** framing the FP10 scenarios and the R&I policy options shaped by five key perspectives underpinning the Action Roadmaps. Building on the preceding Working Paper, this document seeks to advance the debate on the future of the EU R&I Framework Programme, offering strategic pathways for a cohesive, resilient, and sustainable European innovation ecosystem.

## From Multi-Actor Insights to Needs-driven R&I Action Roadmaps



**Literature Review:** Analysed key EU foresight documents, strategic plans, JRC Reference Scenarios, position papers, and EC expert group reports to extract critical insights, serving as a foundation for scenario development and contextual understanding.

**Benchmarking:** Evaluated the EU's global standing in innovation by comparing strategic indicators with international peers, identifying key strengths, gaps, and opportunities to enhance competitiveness.

**Modelling:** Leveraged advanced language learning models (LLMs) to simulate scenario narratives, ensuring data-driven accuracy, narrative plausibility, and internal coherence.

**Critical Issues Analysis:** Explored key drivers, barriers, opportunities, and threats across technological, economic, environmental, political, social, ethical, and spatial dimensions to enrich scenario development.

**Wild Cards and Weak Signals:** Examined low-probability, high-impact events and emerging trends to uncover transformative possibilities and enhance the robustness of the scenarios.

**Brainstorming:** Conducted structured brainstorming sessions with expert teams to refine and expand scenario-specific opportunities, challenges, and strategic insights.

**Genius Forecasting:** Drew on the expertise of leading figures in policy, academia, and industry to anticipate disruptive trends and their potential impacts on the R&I landscape.

**Scenario Writing:** Integrated diverse inputs into compelling narrative scenarios, framing *Fractured Futures* and *Converging Horizons* as contrasting pathways to guide FP10 policy directions.

**Scenarios Workshop:** Engaged RTO leaders in evaluating and prioritising General Prosperity Indicators (GPIs), with a particular focus on advancing the EU's Green and Digital transitions.

**General Prosperity Indicators (GPIs):** Triggered discussions on comprehensive metrics to assess health, economic resilience, sustainability, and cohesion, integrating existing indicators and identifying key gaps.

**Multi-Actor Workshop:** Brought together experts from research, technology, academia, industry, policy, and international organisations, including leading European and international organisations, to explore cutting-edge foresight methods for strengthening Europe's innovation landscape.

**Action Roadmapping:** Collaboratively developed five detailed Action Roadmaps, each comprising 10 actionable strategies across dimensions like Momentum, Foresight, Resources, and Transformation. This process fostered adaptable policy frameworks to address grand challenges, harness global opportunities, build resilience, promote inclusivity, lead in manufacturing, and secure sustainable futures for Europe's R&I ecosystem.



## Vision I: Fractured Futures



### Competing Values, Uneven Progress

In *Fractured Futures*, the world is increasingly divided not only by geography or ideology but also by conflicting priorities, competing values, and inequitable access to resources. Nations and communities pursue divergent strategies amid crises, leading to fragmented development marked by conflicting priorities and inequitable access to resources. Some regions embrace technological innovation and climate adaptation, while others cling to traditional industries or regional alliances to safeguard resources and preserve cultural identity. As a result, progress is patchy, uneven, and often misaligned with global stability.

#### Key Features

##### Geopolitics and Power Dimension

The geopolitical landscape is increasingly defined by regional blocs and shifting alliances, as countries prioritise self-interest over collective action. Nationalist policies dominate, with countries prioritising self-interest over collective action. Alliances shift unpredictably, as new powers emerge and traditional global leaders struggle to maintain their influence. In this fractured world, access to critical resources like rare earth metals and clean water becomes a flashpoint for conflict, with nations leveraging economic sanctions and supply chain manipulation as weapons.

<b>Defence and Security Dimension</b>	<p>The security landscape is volatile, dominated by cyberattacks, misinformation campaigns, and battles over limited resources. Nations invest heavily in defence technologies, particularly in AI-driven surveillance and autonomous systems, but the uneven distribution of these capabilities exacerbates power imbalances. Resource resilience is a key battleground, with wealthier nations securing access to food and energy through monopolistic trade policies, leaving others vulnerable to shortages and instability. Climate-induced migration further strains national security, as borders harden, and conflicts escalate over land and infrastructure.</p>
<b>Techno-Economic Dimension</b>	<p>Technological innovation continues but is increasingly monopolised by a few powerful actors, such as tech giants and militarised states. AI-driven economies flourish in urban centres, where automation and digitisation enable rapid growth. However, rural areas and less developed nations fall further behind, unable to afford or access cutting-edge technologies. Economic disparities deepen as wealthier nations capitalise on climate-resilient infrastructure and genetic engineering, while others face deteriorating economies and resource scarcity. The global trade system fractures, giving rise to regional trade hubs that operate independently of one another.</p>
<b>Socio-Cultural Dimension</b>	<p>Cultural and societal divides widen. Urban centres become hyper-digitised enclaves, fostering innovation and economic growth but also creating isolated bubbles of privilege. Rural areas struggle with limited infrastructure and declining populations, amplifying the urban-rural divide. Ethical concerns around AI, biotechnology, and environmental justice spark protests and social movements, but their influence is often localised and lacks coordination. Trust in political institutions is at an all-time low, as citizens perceive governments as either complicit with or powerless against the dominance of powerful corporations.</p>
<b>Spatial Dimension</b>	<p>Urban areas are the primary beneficiaries of techno-economic advancements, while rural regions become increasingly marginalised. Infrastructure investments focus on urban resilience, such as smart cities and climate-proof housing, but neglect rural connectivity and development. Intergenerational tensions arise, as younger populations migrate to urban centres in search of opportunities, leaving older generations behind in struggling rural communities. Spatial inequalities exacerbate socio-economic divides, making equitable development a dream.</p>
<b>R&amp;I Policy Dimension</b>	<p>Research and innovation (R&amp;I) efforts are fragmented and often driven by short-term national interests. Policies favour proprietary technologies over open knowledge-sharing, with powerful nations and corporations dominating the R&amp;I agenda. Ethical considerations in R&amp;I are often sidelined, as competition for technological supremacy overshadows collaborative approaches. Funding disparities between regions create innovation hubs in wealthy urban areas while leaving rural and less developed regions without support for scientific and technological advancement.</p>

## R&I Policy Options inspired by Fractures Futures

In response to the *Fractured Futures* scenario in Europe, implementing focused and adaptive targeted R&I policies is vital to counter the challenges of a fragmented landscape. These policies address pressing issues like regional inequalities, critical resource dependencies, and technological divides. Below is a list of top 3 illustrative R&I Policy Options, structured across three timeframes – Short-Term (2024-2027), Medium-Term (2028-2034), and Long-Term (2035 and beyond) – designed to enhance resilience, foster transformative innovation, and ensure sustainable regional growth.

### *R&I Policy Options in the Short-Term (2024-2027)*

- **Strengthening Regional Resilience through Decentralised Energy Systems:** Invest in localised energy solutions, community-oriented microgrids, and distributed renewable energy technologies, with subsidies for cutting-edge, scalable energy storage R&D.
- **Localised Climate Adaptation Initiatives:** Fund region-specific carbon capture and storage (CCS) projects, biodiversity conservation technologies, early-warning systems, and climate adaptation technologies tailored to climate-vulnerable and at-risk areas.
- **Decentralised Digital and AI Innovation:** Support the development of decentralised AI models and regionally tailored ethical frameworks, and region-specific applications, particularly for economically and technologically under-resourced regions.

### *R&I Policy Options in the Medium-Term (2028-2034)*

- **Development of Regional Green Tech Hubs:** Establish cross-border green tech hubs focusing on renewable energy, waste management, precision agriculture systems, and climate-resilient infrastructure technologies.
- **Regional Circular Economy Initiatives:** Provide grants for localised recycling technologies, circular economy projects, eco-design innovation, and e-waste recovery initiatives.
- **Technological Solutions for Sustainable Agriculture:** Invest in R&D for climate-resilient farming practices, precision agriculture tools, lab-grown meat alternatives, biotech-enabled food innovations, and sustainable regional food production systems.

### *R&I Policy Options in the Long-Term (2035 and beyond)*

- **Strengthening European Digital Autonomy:** Invest in large-scale, pan-European R&I projects focusing on digital sovereignty, next-generation cybersecurity frameworks, and the development of open-source digital frameworks.
- **Advanced Resource Sovereignty and Sustainability:** Develop region-specific resource-sharing platforms focusing on sustainable water, energy, and waste management, as well as environmentally conscious local resource extraction alternatives.
- **Localised Education and Workforce Transformation:** Support education initiatives focused on digital literacy, AI ethics, advanced green technologies, and renewable energy skills, ensuring access to quality education across urban and rural regions.



## R&I Action Roadmap to Respond to Grand Challenges

The following actions provide a cohesive set of policy directions across *Momentum, Foresight, Resources, Mobilisation, Aptitude, Attitude, Catalysts, Fosterers, Transformation, and Sustainability*, specifically designed to respond to grand challenges of the *Fractured Futures* vision. Each recommendation blends short-term, medium-term, and long-term approaches to foster cross-border collaboration, local resilience, and a green, inclusive future for Europe.

Momentum	Foresight	Resources	Mobilisation
Mobilise political leadership by showcasing successful, localised energy solutions, circular economy models, and sustainability frameworks to inspire broad political action towards a self-sufficient, green future.	Implement horizon scanning, trend analysis and scenario planning for early detection of resource shortages, enabling proactive, cross-border adaptation strategies in energy, health, and technology sectors to mitigate potential disruptions.	Develop diversified funding models for regional innovation hubs, with a focus on decentralised technologies, climate resilience, renewable energy, and equitable education for underserved and rural regions.	Foster strong public-private partnerships, institutional collaboration and community-driven initiatives to address local climate adaptation challenges, ensuring the rapid scaling of solutions with EU-wide applicability.
Aptitude		Attitude	
Build leadership and technical skills through advanced training in green technologies, AI-enabled digital systems, and sustainable practices, ensuring that communities across Europe have the capacity to drive innovations that overcome fragmented development.		Encourage a mindset of empathy, collaboration, and shared accountability among governments, businesses, and citizens, inspiring collective ownership and responsibility towards sustainable development goals, particularly in addressing the needs of vulnerable regions.	
Catalysts		Fosterers	
Invest in pilot projects focused on decentralised technologies like local renewable energy grids, urban green infrastructure, and community-driven biodiversity initiatives, fostering rapid scaling of solutions that promote broader regional and cross-border transformations.		Strengthen regional innovation ecosystems through intellectual property management frameworks, shared innovation spaces, and innovation accelerators to protect, exchange, and scale sustainable solutions across regions to boost knowledge valorisation, co-creation and sharing.	
Transformation		Sustainability	
Facilitate economic and governance transformations by integrating local authorities into EU-wide climate and sustainability frameworks, ensuring cross-border collaboration and alignment with the shared vision of a resilient, green, inclusive, and digital economy.		Ensure long-term sustainability by embedding circular economy principles in all R&I policies, promoting systemic changes in consumption behaviours, resource efficiency, green infrastructure and eco-design to minimise ecological footprints across the EU.	

## Vision 2: Converging Horizons



### Shared Growth, Shared Future

In *Converging Horizons*, the world has chosen collaboration over division, uniting across borders and sectors to address shared challenges and opportunities. Guided by mutual trust and a commitment to long-term resilience, nations align policies to foster sustainable growth, just resource allocation, and social well-being. This vision embodies the possibility of a harmonised future where humanity thrives collectively.

#### Key Features

##### Geopolitics and Power Dimension

Geopolitics in this scenario is characterised by cooperation and multilateralism. Regional and global institutions are revitalised, enabling coordinated responses to climate change, economic inequality, and global health crises. Power is more evenly distributed, with smaller nations and regions playing active roles in shaping global policy. Trade agreements are green-focused, promoting sustainability and reducing dependency on finite natural resources. The EU emerges as a leader in this global collaboration, demonstrating that unity and innovation can coexist.

Defence and Security Dimension	Defence and security are reimagined as pillars of resilience rather than dominance. Investments focus on cybersecurity, climate adaptation infrastructure, and disaster response capabilities. Collaborative defence pacts prioritise the protection of shared resources and global commons, such as oceans, forests, and the atmosphere. R&I drives the development of ethical AI and peacekeeping technologies, reducing the prevalence of military conflicts. Migration policies are humane and equitable, addressing the root causes of displacement and fostering integration.
Techno-Economic Dimension	The global economy transitions toward a circular, sustainable model. Advances in AI, renewable energy, and biotechnology fuel green growth and equitable development. Public and private sectors collaborate to ensure ethical standards, accountability, and transparency in technological innovation. Automation and AI are harnessed to reduce inequality, with policies ensuring job transitions and lifelong learning opportunities. International data governance frameworks promote privacy, security, and equitable access to information.
Socio-Cultural Dimension	Social cohesion is high, driven by inclusive policies and participatory governance. Community well-being is prioritised, with mental health, free time, and cultural engagement recognised as essential to prosperity. Citizen-led global assemblies foster bottom-up innovation and collective problem-solving, amplifying diverse and marginalised voices in decision-making. Ethical debates around AI, genetic engineering, and sustainability are addressed openly, fostering trust and accountability.
Spatial Dimension	Urban and rural areas are interconnected through smart infrastructure, enabling equitable access to resources and opportunities. Rural regions thrive as hubs for sustainable agriculture, renewable energy, and ecotourism, complementing the technological advancements of urban centres. Urban-rural migration flows stabilise, supported by policies that enhance rural connectivity, education, and healthcare. Spatial planning ensures that all regions actively contribute to and benefit from economic and technological advancements.
R&I Policy Dimension	R&I policies are central to this collaborative vision, guided by long-term goals of sustainability, equity, and resilience. Open knowledge-sharing accelerates innovation, while ethical frameworks ensure technologies serve societal needs. Investments in transformative technologies (e.g. advanced materials, autonomous systems, and green mobility) are balanced with efforts to address societal challenges like health equity, education, and climate change. Interdisciplinary research flourishes, integrating the natural and social sciences to tackle complex global issues.

## R&I Policy Options inspired by Converging Horizons

The following R&I policy options offer short, medium, and long-term strategies to capitalise on the transformative potential of the *Converging Horizons* vision. By advancing green innovation, fostering inclusive growth, strengthening global governance, and addressing pressing challenges like climate change, social equity, and health, these policies pave the way toward a prosperous, and resilient future.

### *R&I Policy Options in the Short-Term (2024-2027)*

- **Strengthening Multilateral R&I Collaboration:** Establish or enhance international R&I platforms for shared global challenges like climate change, energy, health crises, and digital transformation challenges to maximise resource-sharing and expertise.
- **Promoting Green Trade Agreements:** Develop trade agreements focused on sustainability, technology transfer, and green jobs to accelerate the flow of green technologies and renewable energy adoption across developing nations.
- **Funding for Green Innovation and Ethical AI:** Increase public and private investments in green technologies, ethical AI research, and inclusive innovation ecosystems to enable equitable, sustainable technological advancements aligned with global sustainability goals.

### *R&I Policy Options in the Medium-Term (2028-2034)*

- **Global Green Innovation Hubs:** Establish regional green tech hubs focusing on renewable energy, sustainable agriculture, clean water technologies, and cross-border collaborative platforms.
- **Advanced Collaborative Defence and Security Research:** Promote R&I in cybersecurity, climate security, disaster response technologies, and peacekeeping to protect shared global resources like oceans, forests, and biodiversity.
- **Long-Term AI for Sustainability and Equity:** Expand R&I investments in AI applications for sustainability, equity, global governance, and resource efficiency, ensuring that AI systems advance ethical standards, social equity, and environmental resilience.

### *R&I Policy Options in the Long-Term (2035 and beyond)*

- **Global Innovation Ecosystem for Sustainability:** Establish a globally integrated innovation ecosystem focusing on sustainability, ensuring R&I efforts address shared challenges such as climate change, inequality, biodiversity loss, and social resilience.
- **Ethical Global AI and Data Governance:** Develop global AI and data governance frameworks ensuring privacy, security, transparency, equitable access, and accountability for technology's equitable benefits.
- **Promoting Global Health Innovation:** Establish global R&I initiatives to focus on health innovation and equitable access to affordable healthcare technologies, pandemic preparedness, and universal health coverage for marginalised populations.



## R&I Action Roadmap to Respond to Grand Opportunities

The following actions are aligned with the *Converging Horizons* vision, focusing on collective sustainability, equity, and long-term resilience. They aim to drive EU leadership and global collaboration by addressing critical sustainability challenges across all key aspects of innovation, from momentum and foresight to transformation and sustainability.

Momentum	Foresight	Resources	Mobilisation
Harness EU's leadership in sustainability by championing global green technology frameworks, harmonised standards, and regulations, catalysing global collaboration to ensure a unified transition towards a circular, sustainable future.	Establish strategic foresight mechanisms to anticipate emerging sustainability challenges, transformative technologies, societal trends, and global governance shifts, aligning R&I investments with evolving demands in energy, climate, and digital security.	Expand funding for large-scale, transnational projects that focus on renewable energy infrastructure, sustainable agriculture, climate-resilient water systems, and advanced technologies, ensuring equitable access to resources for both urban and rural regions.	Engage cross-sectoral public-private partnerships and local governments and community initiatives to co-develop climate adaptation strategies, ensuring coordinated mobilisation of resources to scale up sustainable innovations across all EU regions.
Aptitude		Attitude	
Invest in leadership development and cross-sector skills training, and entrepreneurial education to cultivate a workforce capable of driving sustainable innovation, fostering creative problem-solving and agility in responding to evolving sustainability needs.		Foster a culture of empathy, compassion, accountability, and shared responsibility across communities, businesses, and governments to ensure collective action for sustainability, climate resilience, environmental regeneration, and ecosystems restoration.	
Catalysts		Fosterers	
Invest in and scale decentralised green technology pilots, such as renewable microgrids and local biodiversity initiatives, and community-driven waste management solutions, creating sustainable models for systemic and cross-border change.		Strengthen EU-wide networks of innovators and entrepreneurs by promoting collaborative platforms regional innovation clusters, and cross-sector mentorship networks for knowledge-sharing and diffusion of sustainable solutions.	
Transformation		Sustainability	
Accelerate systemic transformation in key sectors (e.g., energy, agriculture, transport) through circular economies, and nature-based solutions ensuring these transitions align with environmental goals and equitable economic growth.		Ensure long-term environmental, social, and economic sustainability by embedding circular economy principles and sustainability indicators into all EU policies, fostering equitable, intergenerational benefits.	

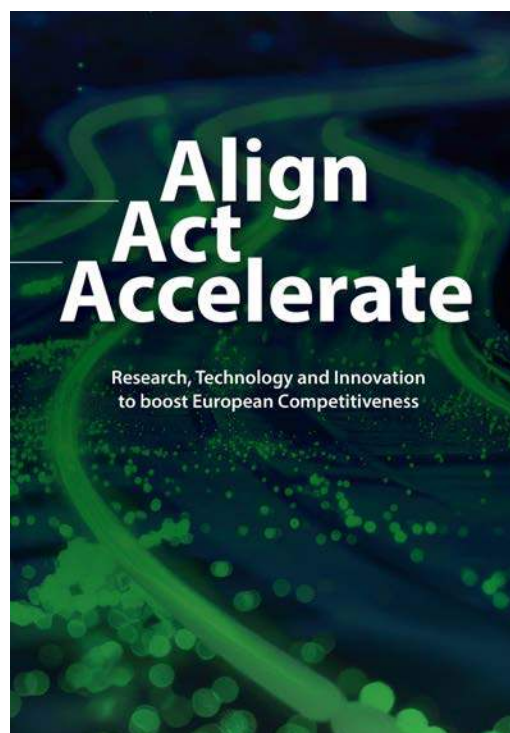
## Vision 3: Align, Act, Accelerate

The 2024 European Commission Expert Group Report ‘**Align, Act, Accelerate: Research, Technology and Innovation to Boost European Competitiveness**’ outlines 12 recommendations to strengthen Horizon Europe and guide future R&I policy. By prioritising resilience, inclusivity, and transformative technologies, the report addresses Europe’s strategic challenges while fostering climate-resilient innovation, long-term sustainability and global competitiveness. Its insights align with the potential realities of the contrasting *Fractured Futures* and *Converging Horizons* scenarios.

In the challenging *Fractured Futures* scenario, the report’s emphasis on securing Europe’s strategic autonomy through sustained investments in critical resources, emerging technologies, and resilient supply chains becomes indispensable. The call for dual-use R&I programmes addresses the blurred lines between civilian and defence needs, ensuring that Europe remains responsive and adaptable amid shifting alliances and emerging threats. By recommending targeted support for underrepresented regions, the report also aligns with the need to counteract the uneven progress inherent in this vision, strengthening cross-regional collaboration and promoting greater regional stability and capacity-building within Europe’s fractured landscape.

The aspirational *Converging Horizons* vision finds strong alignment with the report’s recommendations to foster enhanced cross-border cooperation and Open Knowledge. The focus on societal challenges, including climate change adaptation, biodiversity loss, and equitable development, mirrors this vision’s emphasis on collective solutions to shared problems. By proposing inclusive governance structures and greater investments in transformative technologies like AI and circular manufacturing, the report reinforces the cooperative ethos of *Converging Horizons*, helping to position the EU as a global frontrunner in equitable and sustainable innovation.

Introducing the *Societal Challenges Council*, *Industrial Competitiveness Council*, and *dual-use R&I programmes*, as proposed by the Expert Group on the Interim Evaluation of Horizon Europe, could catalyse unexpected breakthroughs in climate adaptation, circular manufacturing, and AI-driven defence technologies. These governance innovations enable swift responses to global challenges, fostering collaborative R&I ecosystems and inclusive policies. By bridging societal needs with cutting-edge research, these actions align Europe with the *Converging Horizons* vision of shared growth and sustainability.



## R&I Action Roadmap to Boost European Competitiveness

The **Centre for Foresight and Internationalisation (CFI)** synthesised the report's recommendations into an actionable roadmap that incorporates key aspects from both visions. It ensures Europe's capacity to adapt to *Fractured Futures* by bolstering resilience, strategic autonomy, and targeted investments while also addressing the collaborative potential of *Converging Horizons* through inclusive R&I policies and a focus on global sustainability goals. This approach secures both Horizon Europe's and FP10's relevance across contrasting futures.

Momentum	Foresight	Resources	Mobilisation
Align R&I with EU strategic priorities, and integrate transformative investments to strengthen Europe's competitiveness, resilience and leadership in clean energy, digital innovation, and advanced manufacturing technologies.	Implement agile structures, experimental units, and a nuanced international collaboration strategy recognising countries as partners, competitors, or strategic rivals to align R&I strategies with technological and geopolitical challenges.	Expand the Framework Programme budget to €220 billion, secure long-term investments in critical infrastructures and optimise resource allocation through co-funding mechanisms linking EU and Member State efforts with strategic priorities.	Engage underrepresented regions, SMEs, and civil society with tailored initiatives, inclusive programmes, and structural fund synergies to ensure broad participation and societal impact across Europe's R&I ecosystem.
Aptitude		Attitude	
Strengthen talent pipelines with enhanced mobility, interdisciplinary training, and institutional collaboration to attract innovators, address skills gaps, and build Europe's capacity for advanced, sustainable, and inclusive R&I.		Simplify processes by adopting "trust-first / evaluate-later" mechanisms, reduce administrative burdens, streamline redundant programmes, and foster inclusivity to broaden participation and maximise Horizon Europe's reach and impact.	
Catalysts		Fosterers	
Develop innovation procurement programmes and adaptive platforms for scaling technologies, enabling rapid exploitation, market impact, and adoption of cutting-edge manufacturing and clean energy solutions across industries.		Strengthen partnerships and governance to align R&I activities with EU policies, creating coherence, enabling precompetitive collaboration, and linking innovations to societal and economic outcomes across Member States.	
Transformation		Sustainability	
Integrate dual-use technologies into R&I frameworks, optimising innovation for civilian and defence needs while advancing systemic change through disruptive and transformative innovations addressing sustainability and security challenges.		Establish a Societal Challenges Council to prioritise biodiversity loss, planetary boundaries, mental health, and climate adaptation, linking missions with governance, regulatory frameworks, and societal engagement for collective resilience.	

## Vision 4: Manufacturing R&I for Competitiveness

The Joint Position Paper on FP10, by ManuFuture ETP, EIT Manufacturing KIC, and EFFRA, outlines key priorities to strengthen Europe's manufacturing sector, bolster strategic resilience, and enhance autonomy. Emphasising advanced manufacturing technologies, it advocates for increased R&I funding, improved cross-border knowledge flow, and inclusive policies that bridge regional disparities. These R&I policy actions are key in addressing the societal challenges and harnessing the opportunities presented by the contrasting *Fractured Futures* and *Converging Horizons* visions.

In a world characterised by competing values and uneven progress, the paper's focus on advanced manufacturing innovation and technological sovereignty becomes critical. The call for strengthening European supply chains, particularly in defence and critical industries, addresses vulnerabilities arising from external dependencies and geopolitical uncertainties.

By linking civil and military R&I, the paper aligns with the need for resilience in resource-scarce environments, adaptive innovation, and volatile security landscapes.

Its emphasis on precompetitive research and cross-regional collaboration can mitigate the monopolisation of technological advances by a few powerful actors, fostering innovation across diverse and underserved regions. Furthermore, the prioritisation of green and circular manufacturing technologies helps reduce economic disparities between urban and rural areas. These innovations enable localised production, empowering marginalised regions to thrive despite limited resources, while the inclusion of SMEs and community-driven enterprises ensures that fragmented economic hubs remain interconnected.

In a collaborative world focused on shared growth and resilience, the paper's emphasis on fostering inclusive manufacturing ecosystems aligns closely with the vision. By advocating for Open Knowledge, interdisciplinary partnerships, and cross-sector collaboration, it supports long-term strategies that unite academia, industry, and SMEs to tackle global challenges like climate change and resource efficiency. Advanced manufacturing technologies enable sustainable, circular production models that contribute to EU climate neutrality goals while ensuring economic equity.

The paper's focus on agile R&I governance and bidirectional knowledge flow facilitates swift and scalable innovation, critical for responding to evolving global needs. By making the EU attractive for young innovators and skilled professionals, it contributes to equitable growth, cross-generational knowledge-sharing, and ensures that rural and urban areas benefit from technological advances.





## R&I Action Roadmap to Manufacturing Leadership

Based on the key messages from the Joint Position Paper by ManuFuture ETP, EIT Manufacturing KIC, and EFFRA, the CFI team has crafted an actionable roadmap. This roadmap outlines strategic R&I policy options to prioritise manufacturing innovation, address workforce skills gaps, and foster sustainability, competitiveness, and resilience in Europe's research and innovation ecosystem.

Momentum	Foresight	Resources	Mobilisation
Prioritise manufacturing as a transversal area, linking civil and defence R&I, increasing FP10 funding proportionally to ambition, and addressing critical dependencies (resource, industrial, technological, supply chain, defence, R&D investment) to secure EU's leadership and competitiveness.	Implement agile FP10 structures with bidirectional knowledge flows, adaptive instruments, and bottom-up approaches to quickly address manufacturing bottlenecks, align priorities, and adapt to evolving strategic challenges and technologies.	Provide seed funding for precompetitive research in advanced manufacturing, engage European financing entities (such as the EIB and EIF) for scale-up investments, and strengthen public-private partnerships to drive sustainable, circular, and competitive innovations.	Strengthen cross-sector synergies by engaging SMEs, academia, midcaps, and underrepresented regions through tailored platforms, streamlined processes and incentives to create resilient, interconnected, and innovative manufacturing ecosystems in the EU.
Aptitude		Attitude	
Integrate advanced education and skills training (e.g. digital transformation and strategic foresight) into FP10, focusing on young scientists and engineers, to address manufacturing talent gap and establish the region as a hub for innovation talent.		Foster inclusivity by engaging modest innovator regions, embedding Open Knowledge principles, and ensuring SME participation, enabling broad collaboration and equitable contributions across Europe's manufacturing R&I landscape.	
Catalysts		Fosterers	
Develop frameworks for rapid exploitation of research outcomes, focusing on technology-driven calls with expectations aligned to readiness levels, enabling faster commercialisation and greater impact for manufacturing innovations.		Establish coordinated governance for advanced manufacturing, align with EIT Manufacturing KICs, and foster precompetitive R&I collaboration across academia, industry, and SMEs to build robust innovation ecosystems.	
Transformation		Sustainability	
Develop advanced manufacturing ecosystems with circular economy integration, enabling scalable, resource-efficient production models and systemic transformations to enhance Europe's sustainability, competitiveness, and global technological leadership.		Leverage advanced manufacturing innovations to drive green transitions, enabling resource-efficient, reusable, and repairable products while supporting long-term R&I strategies to sustain competitiveness and environmental resilience in Europe.	

## Vision 5: Inclusive, Agile, and Impact-Driven R&I

The Polish Chamber of Commerce for High Technology (IZTECH) represents over 200 high-tech institutions and enterprises in Poland. Its 2024 Position Paper for the EU's FP10 highlights strategies for advancing innovation, fostering inclusivity, and ensuring sustainability to strengthen Europe's research and innovation ecosystem. By addressing funding disparities, governance challenges, and accelerating technological integration, the paper provides a strong foundation for understanding and adapting to contrasting future scenarios: *Fractured Futures* and *Converging Horizons*.

In a fragmented world, such as *Fractured Futures*, where geopolitical tensions dominate and resources are unevenly distributed, IZTECH's emphasis on targeted funding, SME support, and decentralised innovation becomes critical. The Position Paper's call for distinct Mission financing aligns with fractured priorities, ensuring that short-term national interests do not erode Europe's strategic R&I capabilities or disrupt long-term innovation potential.

Its focus on synergies between EU and national funding addresses the disparities that exacerbate urban-rural divides and consolidate the power of monopolistic actors in innovation. Furthermore, the paper's attention to integrating underrepresented regions resonates with the need to mitigate spatial inequalities, foster equitable innovation ecosystems, and prevent the marginalisation of rural communities.

In a collaborative future marked by global unity, as in *Converging Horizons*, IZTECH's proposals for inclusivity, sustainability, and interdisciplinary research are directly relevant. The Position Paper's vision of harmonising R&I governance and fostering partnerships aligns with multilateral approaches to addressing shared challenges such as climate change, biodiversity loss, and resource scarcity. By promoting gender equity, interdisciplinary Excellence Hubs, and the circular economy, it reflects the socio-cultural cohesion and ethical underpinnings of this vision. The emphasis on green technologies and social readiness frameworks also supports a world where equitable technological integration, inclusive economic growth, and environmental resilience are prioritised.

The IZTECH Position Paper highlights the importance of integrating 'Widening countries' into R&I frameworks using tailored mechanisms, inclusive funding strategies, and interdisciplinary approaches to enhance participation, build regional capacity, and reduce persistent regional disparities in innovation ecosystems.



## R&I Action Roadmap to More Inclusive Futures

The CFI team has used IZTECH’s insights to prepare an action roadmap for key R&I policy options. By addressing funding, governance, inclusivity, sustainability, and technological integration, this roadmap outlines actionable strategies to foster competitiveness, societal impact, and systemic progress across diverse sectors and regions. This ensures that Europe’s R&I policies remain adaptable and impactful across contrasting futures.

Momentum	Foresight	Resources	Mobilisation
Double FP10’s budget and establish distinct Mission funding streams, ensuring comprehensive TRL coverage and preventing resource dilution to drive innovation, competitiveness, and board-based technological progress across Europe.	Implement horizon scanning and scenario planning, involving local authorities to align EU-wide governance, anticipate sustainability challenges and integrate disruptive technologies for a greener, digitally transformed, and future-ready research landscape.	Simplify SME application processes, allocate between 30-40% of budgets to SMEs, and harmonise EU-national funding to maximise synergies, ensuring equitable access to resources and more inclusive research and innovation ecosystem participation.	Foster international collaboration and decentralised R&I by supporting community-led biodiversity and microgrid initiatives, driving scalable transformations in underrepresented regions and enhancing EU’s global R&I leadership.
Aptitude		Attitude	
Enhance Research Managers and Administrators (RMA)’s professionalisation and interdisciplinary networking while balancing top-down and bottom-up calls to adapt R&I implementation processes to shifting trends and dynamic market demands.		Integrate “islands of excellence” to expand inclusivity, embedding gender-balanced criteria, and fostering equity-focused innovation to ensure broad, diverse societal engagement and shared ownership of impactful R&I projects.	
Catalysts		Fosterers	
Incorporate Social Readiness Levels (SRL) and Environmental Technology Verification (ETV) to align innovations with societal needs, reduce resistance, and accelerate market acceptance of sustainable technological solutions.		Simplify partnerships, align European Institute of Innovation and Technology (EIT) and European Innovation Council (EIC) synergies, leverage national systems to enhance collaboration, scale sustainable innovations, and streamline processes.	
Transformation		Sustainability	
Embed circular economy principles and distinct legal frameworks into R&I, targeting resource efficiency, systemic transformation, and addressing societal challenges with adaptive, impact-focused research-driven solutions.		Promote green technologies and decentralised innovation, integrating renewable energy grids and community biodiversity initiatives to combat climate change and ensure scalable local-to-global transitions for a sustainable future.	

## R&I Policy Options Reflecting Shared Perspectives

Analysing the five visions – two **Frontier Visions** by the Centre for Foresight and Internationalisation (CFI), the Joint Position Paper by ManuFuture ETP, EIT Manufacturing KIC, and EFFRA, the Polish Chamber of Commerce for High Technology (IZTECH) Position Paper, and the European Commission Expert Group Report – reveals critical, cross-cutting R&I policy priorities. Despite diverse contexts, shared priorities such as environmental sustainability, inclusivity, and transformative technological innovation emerge as essential for shaping and aligning Europe's R&I strategies across both fragmented and collaborative scenarios.

- **Strengthening Regional and Global Green Tech Hubs:** This policy option reflects broad, strategic consensus across all visions. The *Fractured Futures* vision emphasises regional hubs for resilience, while *Converging Horizons* envisions globally integrated hubs promoting long-term sustainability. ManuFuture, EIT, and EFFRA highlight hubs as vital for manufacturing innovation, aligning with IZTECH's push for decentralised green technologies and the Expert Group's call for adaptive and collaborative innovation ecosystems.
- **Promoting Circular Economy and Resource Efficiency:** Circular economy principles are integral to bridging sustainability and economic competitiveness in all visions. CFI's *Converging Horizons* promotes these principles globally, while *Fractured Futures* integrates them into regional frameworks to reduce fragmentation and promote regional self-reliance. The Expert Group and IZTECH advocate embedding circular economies in all R&I policies, underscoring their transformative and systemic importance.
- **Investing in Decentralised Energy and Technology Systems:** This policy bridges gaps in fragmented scenarios and enhances inclusivity in collaborative futures. *Fractured Futures* focuses on localised energy grids and decentralised AI models for strengthening regional autonomy, while *Converging Horizons* scales these solutions globally. Both position papers and the Expert Group recognise the dual role of decentralisation in boosting resilience and fostering equity, particularly in underrepresented regions.
- **Expanding Funding and Synergies Across Frameworks:** In all visions, expanded funding and aligned EU-national frameworks address uneven progress in *Fractured Futures* and support global cooperation in *Converging Horizons*. This aligns with the Expert Group's €220 billion FP10 proposal, IZTECH's emphasis on SME-focused funding, and EFFRA's call for strategic manufacturing investment and cross-sectoral innovation.
- **Fostering Inclusive R&I Ecosystems:** Inclusivity is universally valued, with *Fractured Futures* countering regional divides and *Converging Horizons* amplifying global equity. IZTECH's support for underrepresented regions, ManuFuture's focus on SMEs, and the Expert Group's inclusive governance strategies highlight the potential of diverse, equitable participation to drive transformative societal impacts.

Together, these shared priorities illustrate Europe's capacity to align R&I policies for long-term resilience, global competitiveness, and shared prosperity across fragmented and unified futures.



## R&I Policy Options Reflecting Unique Perspectives

To shape transformative futures, Europe must embrace forward-thinking R&I policies tailored to diverse challenges and opportunities. Addressing fragmented geopolitics and fostering collaborative networks, these policies enable innovative, equitable, sustainable outcomes. Rooted in insights from two Foresight Workshops with over 50 experts, this section highlights 15 original R&I options ensuring resilience, inclusivity, and adaptability in EU's dynamic innovation ecosystem.

Vision	Unique Perspectives
Fractured Futures	<p><b>Strengthening European Digital Autonomy:</b> Focus on pan-European R&amp;I projects, cybersecurity frameworks, and open-source platforms to enhance digital sovereignty, ensuring strategic resilience in fragmented geopolitical environments.</p> <p><b>Localised Climate Adaptation Technologies:</b> Invest in region-specific carbon capture and storage (CCS) projects, biodiversity tools, and early-warning systems to address uneven progress and strengthen adaptive capacity across Europe's diverse regions.</p> <p><b>Decentralised AI Models:</b> Develop ethical, region-specific AI solutions tailored to under-resourced regions to reduce inequalities and bridge technological divides.</p>
Converging Horizons	<p><b>Global Green Innovation Ecosystems:</b> Establish integrated hubs for renewable energy and sustainable agriculture, fostering cross-border collaboration and equitable growth.</p> <p><b>Ethical AI and Data Governance:</b> Create global frameworks ensuring transparency, equitable access, and accountability for ethically driven and inclusive AI-driven solutions in governance and innovation.</p> <p><b>Universal Health Innovation:</b> Develop R&amp;I policies to address global health challenges with equitable access to healthcare technologies and pandemic preparedness.</p>
Expert Group on Interim Evaluation of Horizon Europe	<p><b>Societal Challenges Council:</b> Prioritise issues like mental health, biodiversity loss, and planetary boundaries with integrated missions and governance frameworks.</p> <p><b>Radical Simplification of Funding Processes:</b> Adopt "trust-first" mechanisms to reduce administrative burdens and streamline innovation pathways for accelerated uptake.</p> <p><b>Disruptive Technology Pilots:</b> Establish ARPA-style units for testing breakthrough innovations in real-world scenarios, focusing on high-impact and scalable technologies.</p>
ManuFuture ETP, EIT Manufacturing KIC & EFFRA Position Paper	<p><b>Circular Manufacturing Ecosystems:</b> Create circular manufacturing models integrating advanced materials and resource-efficient processes to reduce waste.</p> <p><b>Bidirectional Knowledge Flows:</b> Strengthen interactions between basic and applied sciences to accelerate the market readiness of innovative solutions.</p> <p><b>Green and Defence Integration:</b> Link civil and military R&amp;I to bolster Europe's strategic autonomy and resilience in critical supply chains.</p>
IZTECH Position Paper	<p><b>Inclusive Excellence Hubs:</b> Develop interdisciplinary hubs integrating underrepresented regions to foster equity in innovation ecosystems.</p> <p><b>Widening SME Participation:</b> Simplify funding processes and incentivise SME engagement to broaden regional representation and enhance innovation capacity.</p> <p><b>Social Readiness Frameworks:</b> Introduce tools assessing societal impacts of R&amp;I to ensure community acceptance, foster trust, and alignment with public needs.</p>

## R&I Priorities Shaped by Wild Cards Frameworks

**Wild Cards**, as defined by Popper et al. (2011) and Ravetz et al. (2011), focus on low-probability, high-impact events capable of disrupting systems and sparking innovation. When paired with Weak Signals – subtle indicators of emerging trends – they form a dynamic foundation for strategic research and innovation (R&I) policy development. The **Frontier Visions** – *Fractured Futures* and *Converging Horizons* – and JRC Reference Scenarios guided the identification of 30 Wild Cards, with five more emerging during an expert workshop in Brussels, totalling 35. Follow-up desk research and advanced analytics distilled 525 insights into emerging technologies, disruptive innovations, and critical technologies, shaping a robust framework for the EU's R&I ecosystem.



Wild Cards span diverse scenarios, from natural disasters and accidental discoveries to geopolitical shocks. They can be grouped as follows:

- **Nature-driven surprises:** External events like pandemics or extreme weather, largely beyond human control.
- **Unintentional surprises:** Arising from human actions, such as accidental discoveries or system breakdowns.
- **Intentional surprises:** Deliberate actions, including cyberattacks or geopolitical conflicts, mitigatable through proactive foresight.

**Weak Signals** provide early, often ambiguous indications of future disruptions. While rigorous analysis is ideal, this project focused on identifying a couple of signals to validate the significance of selected Wild Cards. These signals, derived from desk research and Brussels workshop discussions, highlighted trends in AI for sustainability, renewable energy systems, decentralised governance, and advanced manufacturing, offering preliminary markers of transformative possibilities.

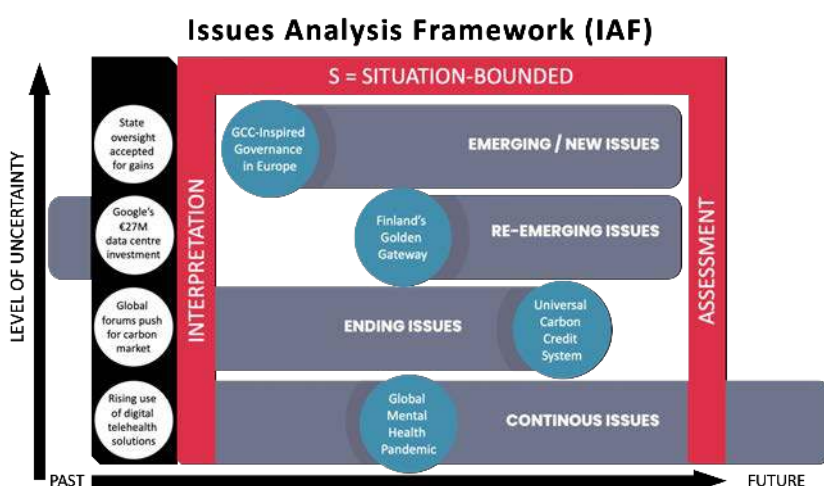
Wild Cards-based frameworks enhance R&I policy resilience by aligning multi-level strategies with the complexities of an unpredictable world. In *Fractured Futures*, they reveal vulnerabilities in decentralised innovation and regional disparities. In *Converging Horizons*, they highlight opportunities for global collaboration and shared progress. Key applications include:

- **Building resilience:** Incorporating Wild Cards into foresight strengthens Europe's capacity to address high-impact disruptions.
- **Fostering innovation:** Wild Cards stimulate breakthroughs in circular economy integration, renewable energy, and AI-driven societal solutions.
- **Policy integration:** Embedding Wild Cards into strategic objectives bridges foresight with actionable R&I frameworks, ensuring adaptability and impact.

## Enabling Transformative Futures

**Wild Cards** serve as a foundational tool for exploring and navigating transformative futures. This section sets the stage for further exploration of Wild Cards-based emerging technologies, societal challenges, and critical technologies in the sections that follow.

Together, the *Issues Analysis Framework (IAF)* and *Action Roadmapping (AR)* approaches offer a comprehensive methodology, combining issue analysis and actionable planning to address transformative challenges and shape the future of research and innovation (R&I). These frameworks have been pivotal in anticipating emerging technologies and disruptive innovations, as highlighted in the chapter on ‘*The Role of Horizon Scanning in Anticipating and Monitoring Emerging Technologies and Disruptive Innovations*’ in the European Commission Joint Research Centre and European Innovation Council (EIC) report on **Technology Foresight for Public Funding of Innovation: Methods and Best Practices**.



The IAF, developed during the iKnow project (2008–2011) was used to identify and categorise 25 Wild Cards, 50 Weak Signals, and over 500 insights. By introducing uncertainty assessment, we anticipated four types of disruptive situations:

- **continuous,**
- **ending,**
- **re-emerging, and**
- **emerging/new issues.**

These insights, supported by focus groups within the CFI team in Warsaw and CFI-Barcelona experts, allowed for a nuanced understanding of potential opportunities and risks. **Action Roadmapping** complemented the IAF by translating foresight insights into actionable strategies focused on four dimensions critical for sustained and disruptive innovations: **Context** (Adapting policies to regular, sustained, or disruptive innovation changes), **People** (Strengthening competences and behaviours to support transformative ideas), **Processes** (Converting ideas into innovative products, services, or business models), and **Impact** (Delivering stability and achieving targeted outcomes).



## R&I Priorities Shaped by Emerging Technologies

The integration of 25 Wild Cards to generate insights on emerging technologies demonstrates the capacity of foresight to inform Research and Innovation (R&I) policy. This process aligns technological advancements with societal and economic priorities, providing Europe with a strategic pathway to measurable impact. Emerging Technology Areas (ETAs), including renewable energy, AI for sustainability, and decentralised governance, bridge the divide between R&I policy frameworks and actionable outcomes.

**Renewable Energy Technologies** such as affordable fusion reactors, solid-state batteries, and smart grid IoT devices epitomise Europe's commitment to sustainability through innovation.

These advancements directly support the policy option of strengthening regional and global green tech hubs, as envisioned in the *Converging Horizons* and *Fractured Futures* scenarios. By fostering interconnected hubs, these technologies enable scalable renewable solutions that bolster energy resilience and support global cooperation. This is particularly relevant to decentralised energy strategies highlighted by IZTECH and the European Commission Expert Group.

**AI innovations**, including ecological impact assessment tools and carbon footprint analysis platforms, streamline decision-making processes and enhance environmental governance. These technologies align with the policy emphasis on promoting circular economy and resource efficiency, facilitating dynamic, data-driven resource management. The systemic importance of circularity, underscored by all five visions, is magnified by AI's ability to optimise material flows and minimise waste, creating synergies between strategic policy and operational action.

**Decentralisation technologies**, such as blockchain-based governance platforms and regional AI models, enable transparent, participatory decision-making. These innovations advance the policy objective of fostering inclusive R&I ecosystems by empowering underrepresented regions and encouraging equity-driven governance. As articulated in *Fractured Futures*, decentralised systems mitigate regional disparities, while in *Converging Horizons*, they scale inclusivity globally. These synergies enhance resilience and amplify societal engagement, critical to Europe's long-term innovation strategy.

Through their alignment with cross-cutting R&I policy options, these ETAs embody a forward-looking approach that links strategic vision with operational implementation. By embedding these technologies in funding frameworks, governance reforms, and decentralised systems, Europe can reinforce its leadership in innovation, sustainability, and inclusivity.





## Emerging Technologies Driving Transformation

This section, inspired by wild cards thinking, explores three transformative emerging technologies – *Next-Generation Mobility*, *Water and Resource Management*, and *AI for Social Impact* – highlighting their potential to drive sustainability, equity, and global innovations.

### Next-Generation Mobility: Hyperloop and Beyond

Advanced transportation systems, such as Hyperloop technologies, revolutionise regional and global connectivity. By enabling high-speed, low-emission transit, Hyperloop reduces fossil fuel reliance while fostering economic integration across trade zones. This next-generation mobility accelerates green tech hubs, driving sustainable progress.



### Water and Resource Management

Energy-efficient desalination and IoT-enabled water systems are essential for sustainable resource management, addressing water scarcity, enhancing resilience in climate-affected regions, promoting circular economy principles, and bridging regional autonomy with global scalability for environmental and economic objectives.



### AI for Social Impact

Artificial Intelligence (AI) for Social Impact leverages ethical systems like explainable AI and policy simulations to address societal challenges with fairness, transparency, and inclusivity. It fosters trust, aligns with inclusive R&I ecosystems, and creates transformative societal impacts across diverse future scenarios.



## R&I Priorities Shaped by Disruptive Innovations

Tackling societal challenges such as governance, inclusivity, and environmental resilience requires innovative approaches that extend beyond conventional frameworks. By employing carefully selected wild cards, this analysis has generated disruptive innovation insights, providing a foundation for policies that link visionary thinking with practical interventions. These insights are particularly focused on bridging gaps in governance, fostering inclusivity, and addressing pressing societal issues like climate resilience and migration.

Disruptive Innovation Areas (DIAs) such as **citizen-driven governance** underscore the pivotal role of participatory frameworks in shaping equitable policies. For instance, *Participatory Governance Models* offer avenues to decentralise decision-making and embed transparency into R&I systems. Similarly, *Citizen-Led Policy Innovation Labs* provide platforms for grassroots innovations to be integrated into national and regional governance frameworks. From an R&I policy perspective, these initiatives demonstrate how empowering citizens can strengthen resilience in fragmented contexts, ensuring local expertise and values are not only heard but also instrumental in driving sustainable innovation.

**Migration resilience** is another domain where disruptive innovations are reshaping policy landscapes. In particular, *Adaptive City Design Models* reimagine urban spaces to accommodate climate-induced migration, ensuring housing, infrastructure, and services adapt to shifting demographics. Additionally, *Citizen-Led Migration Resilience Programmes* empower local communities to co-create solutions tailored to regional challenges, such as scalable housing systems or inclusive urban planning tools. R&I policies focusing on these areas can bridge the gap between urgent response mechanisms and long-term adaptability, aligning global agreements with actionable, localised interventions.

**Ecosystem restoration** presents a compelling narrative for embedding sustainability into R&I strategies. *Dynamic Habitat Protection Zones* utilise real-time ecological data to prioritise areas requiring immediate conservation, while *Global Biodiversity Banks* create structured financial mechanisms to monetise and protect biodiversity services. These innovations exemplify how R&I policies can incentivise private sector engagement in conservation efforts while aligning with public objectives. Tactical actions, like embedding circular economy principles into scaling initiatives and strengthening IP frameworks, can attract private sector engagement and ensure alignment with public goals. Operationally, fostering decentralised innovation through biodiversity projects aligns restoration initiatives with regional needs. By linking these diverse disruptive innovations with actionable R&I policies, Europe can position itself as a leader in addressing societal challenges.





## Driving Ecosystem Resilience through Disruptive Innovation

This section explores transformative approaches to sustainability, migration resilience, and green trade. Disruptive innovations – *Dynamic Carbon Markets*, *Adaptive Migration Strategies*, and *Global Green Technology Ecosystems* – offer actionable pathways to align R&I policies with societal impact.

### Dynamic Carbon and Eco-Incentive Systems

Dynamic carbon markets drive sustainability by linking financial rewards to carbon reduction. Innovations like Dynamic Carbon Offset Ecosystems and Carbon-Neutral Incentive Models enable AI-powered marketplaces and personalised carbon credits, aligning with R&I policies on resource efficiency, circular economies, and accountability.



### Migration and Crisis Resilience

Climate-driven migration requires adaptive R&I strategies. Innovations like Citizen-Led Migration Resilience Programs and Climate Insurance for Displaced Populations link tactical responses with global agreements, fostering equitable adaptation, localised solutions, and societal harmony amid shifting demographics and environmental challenges.



### Green Technology Ecosystems

Global green technology markets hold significant potential. Innovations such as Dynamic Green IP Licensing Models and Green Tech Licensing Hubs suggest frameworks for operational actions like adaptive tech-sharing platforms. These support Europe's vision of global competitiveness through sustainable innovation.



## R&I Priorities Shaped by Critical Technologies

Critical technologies are key to Europe's aspirations for R&I leadership, driving digital transformation, resilience, and sustainability. By employing a structured wild cards analysis, over 100 insights have been distilled, identifying critical technologies that align with R&I priorities addressing systemic challenges.

**Smart grid systems** stand as exemplars of decentralised energy innovation, pivotal for fostering resilient *green tech hubs*. By integrating microgrids and leveraging energy blockchain technologies, these systems enable localised energy independence while maintaining scalability for broader network integration. *Modular energy systems* further provide adaptability in remote or vulnerable regions, ensuring continuity and equity in energy access. These advancements directly support policy imperatives for decentralisation and equity-driven frameworks, strengthening regional resilience while aligning with global sustainability goals.



**Carbon capture technologies and eco-incentive** systems provide essential tools for advancing circular economy principles. Innovations such as *nature-based carbon sequestration solutions* and *AI-powered carbon audit platforms* highlight the dual role of environmental preservation and technological optimisation. By linking carbon capture efforts to transparent financial mechanisms like carbon credit trading, these technologies incentivise systemic resource efficiency while embedding accountability into R&I strategies.

**AI for sustainability** transcends traditional applications, enabling dynamic governance through data-driven platforms. *Tools for ecological impact assessment* and *carbon footprint analysis* illustrate AI's role in fostering informed decision-making processes, optimising material flows, and minimising waste. These capabilities amplify the strategic importance of embedding AI into operational R&I systems, ensuring alignment between high-level policy objectives and actionable outcomes.

**Advanced manufacturing technologies**, such as *low-impact industrial processes* and *digital twins for green infrastructure*, bridge economic competitiveness with environmental stewardship. These innovations support scalable production models, aligning localised economic initiatives with broader ecological goals. Additionally, nature-based solutions integrated into manufacturing processes enable the seamless alignment of industrial growth with biodiversity preservation.



## Digital Trust, Biodiversity Regeneration, and Data Analytics

Critical technologies transform R&I by addressing systemic challenges. *Digital identity* secures participatory governance, *biodiversity restoration* employs AI for ecosystems management, and *advanced analytics* optimise policy-making, aligning innovation with broader sustainability goals.

### Digital Identity and Privacy

Digital identity and privacy technologies safeguard data security while ensuring inclusivity in decentralised systems. Innovations like decentralised digital IDs and secure frameworks protect personal information, empowering participatory governance and aligning R&I goals with trust, inclusivity, and societal resilience.



### Biodiversity Restoration

Biodiversity restoration solutions regenerate ecosystems through AI-guided conservation tools and bioinformatics platforms. Dynamic habitat zones and biodiversity banks incentivise conservation, aligning Europe's R&I strategies with environmental preservation and economic growth, fostering synergies for sustainable development.



### Advanced Analytics

AI-driven advanced analytics enhance policy simulation and governance by integrating diverse data streams to optimise decision-making. Tools like policy simulation AI and ethical governance platforms ensure fairness, enabling Europe to strengthen resilience through evidence-based, inclusive R&I strategies.





## R&I Action Roadmaps: A Multi-Level Approach

### Strategic Actions

**Strategic actions**, shaped by top-level decision-makers, establish long-term priorities to drive innovation, sustainability, and competitiveness. These actions include a significant funding boost for FP10, governance reform, circular economy integration, and transformative R&I frameworks, strengthening Europe's resilience, global leadership, and environmental stewardship. Below are 10 high-level actions addressing advanced manufacturing, dual-use technologies, and climate frameworks, designed to foster sustainable and inclusive growth across the EU.

1. Expand FP10's budget to €220 billion, establish Mission streams, prevent resource dilution.
2. Mobilise leadership showcasing energy, circular economy, sustainability innovations.
3. Harness EU sustainability leadership via global frameworks, standards, cooperation.
4. Align R&I with EU priorities to boost resilience and competitiveness.
5. Facilitate governance transformations integrating local authorities into frameworks.
6. Accelerate transformations through circular economies, nature-based sustainable solutions.
7. Embed circular principles, legal frameworks for resource efficiency, transformation.
8. Integrate dual-use technologies for sustainability and security in R&I.
9. Develop advanced manufacturing ecosystems with circular economy, scalable production.
10. Enable economic transformations through EU-wide climate and sustainability frameworks.

### Tactical Actions

**Tactical actions** bridge strategy and implementation, translating objectives into funding mechanisms, partnerships, and platforms. These 15 mid-level interventions focus on foresight, ecosystem strengthening, inclusivity, and innovation scaling, highlighting agile collaboration strategies, societal alignment tools, and decentralised technology hubs for sustainable growth.

1. Establish foresight mechanisms to anticipate trends and align R&I investments.
2. Implement agile structures and nuanced international collaboration strategies for R&I.
3. Use horizon scanning and planning to anticipate sustainability and technology challenges.
4. Develop funding models for innovation hubs focusing on decentralised technologies.
5. Optimise infrastructure investments through co-funding, aligning EU and MS priorities.
6. Provide seed funding for manufacturing R&D through public-private partnerships.
7. Simplify SME applications and harmonise EU-national funding for inclusivity.
8. Build leadership and skills through training in green technologies and AI.
9. Develop cross-sector skills and entrepreneurial education for sustainable innovation.
10. Develop platforms for scaling technologies and market adoption of innovations.
11. Focus R&D frameworks on rapid commercialisation of technology-driven innovations.
12. Use SRL and ETV tools to ensure societal alignment and market readiness.
13. Strengthen innovation ecosystems with IP frameworks and co-working spaces.
14. Promote networks of innovators, mentorship programs, and regional innovation clusters.
15. Incorporate circular economy principles into rapid innovation scaling initiatives.

## Operational Actions

**Operational actions** are executed by practitioners – Operational actions are executed by practitioners – policymakers, entrepreneurs, researchers, and community leaders – focused on delivering measurable results in key areas of European research and innovation. The 25 actions below showcase diverse, implementation-focused initiatives from the five R&I policy roadmaps. These actions address critical challenges such as climate adaptation, regional inclusivity, green innovation, circular economy integration, and sustainable governance. Examples include horizon scanning to anticipate resource crises, fostering biodiversity and microgrid projects for decentralised innovation, scaling renewable energy systems, and embedding circular economy metrics in R&I frameworks. Additionally, they prioritise advanced education and skills development, closing skills gaps, enhancing interdisciplinary training for Research Managers, and encouraging SME participation through simplified funding mechanisms.

By fostering collaboration, equity-driven innovation, and practical frameworks, these actions link policy to implementation. Decentralised technologies promote inclusivity and resilience, while shared governance aligns biodiversity and health with solutions, enabling Europe to balance immediate needs with sustainable futures.

1. Conduct horizon scanning for early detection of resource crises.
2. Use scenario planning to anticipate sustainability challenges and technological trends.
3. Expand funding for renewable energy, agriculture, and water systems projects.
4. Simplify SME application processes and harmonise funding for inclusivity.
5. Build public-private partnerships addressing local climate adaptation challenges.
6. Engage partnerships for climate adaptation and scale sustainable innovations.
7. Include underrepresented regions in tailored R&I programmes and structural synergies.
8. Foster collaboration and decentralised innovation via biodiversity and microgrid projects.
9. Engage SMEs, academia, and regions through flexible platforms and processes.
10. Enhance mobility and training to attract innovators and close skills gaps.
11. Integrate advanced education and skills in FP10 for young scientists.
12. Enhance Research Managers' interdisciplinary skills to meet emerging trends.
13. Foster empathy and shared accountability for sustainable development goals.
14. Encourage shared responsibility for sustainability across communities and governments
15. Simplify processes with trust-first mechanisms to reduce administrative burdens
16. Expand inclusivity through "islands of excellence" and equity-focused innovation.
17. Pilot decentralised energy grids, urban green infrastructure, and biodiversity projects.
18. Scale decentralised green technology pilots, such as microgrids and biodiversity projects.
19. Strengthen governance to align R&I activities with societal benefits.
20. Align manufacturing governance with EIT Manufacturing KICs for collaboration
21. Simplify partnerships and align EIT and EIC synergies for scalability.
22. Embed circular economy principles in R&I policies for sustainability.
23. Ensure circular economy metrics in all EU R&I policies.
24. Prioritise societal challenges like biodiversity and mental health via dedicated councils.
25. Use advanced manufacturing to drive resource-efficient, reusable, and repairable products.

## R&I Recommendations and Conclusions

Leveraging multiple visions in foresight exercises empowers experts to navigate diverse, contrasting futures and produce actionable R&I policy options. By repositioning experts in transformative contexts, these methods unlock creativity, fostering sound, forward-thinking advice. This section draws six key conclusions and recommendations based on the 50 strategic, tactical, and operational actions presented earlier. These conclusions align with the types of recommendations used in the **SMART Futures Jigsaw** (Popper, 2011), ensuring a comprehensive and adaptive approach to Europe's R&I challenges.

- **Funding and Investments:** The action roadmaps advocate for a substantial increase in the Framework Programme budget, alongside diverse funding approaches such as seed funding, mission-driven streams, and co-funding mechanisms. Instruments include public-private partnerships and innovation pilots to support advanced manufacturing, decentralised technologies, renewable infrastructure, and regional hubs. These investments aim to foster sustainability, circular economies, and systemic transformation, reinforcing Europe's leadership in research and innovation.
- **Policies and actions:** The action roadmaps recommend mobilising leadership through innovation showcases, fostering governance transformations, championing sustainability leadership, and aligning R&I with priorities. Simplified processes, coordinated governance, and dual-use technologies streamline efforts, ensuring scalable, inclusive, sustainable innovation ecosystems driving Europe's green and digital transformation.
- **Initiatives and actors:** The action roadmaps new initiatives emphasise fostering sustainability, inclusivity, and innovation readiness. Highlights include establishing national sustainability councils, integrating Social Readiness Levels, and embedding "islands of excellence" for equity-focused innovation. Initiatives prioritise advanced manufacturing, rural innovation hubs, and frameworks targeting social and environmental transformation.
- **Alliances and partnerships:** The action roadmaps emphasise forging robust alliances through international sustainability partnerships, regional innovation ecosystems, and tailored initiatives for underrepresented regions. Key actions include enhancing talent pipelines, fostering public-private collaborations, and creating networks to link R&I activities with societal and economic benefits across Europe.
- **Basic, applied and futures research:** The action roadmaps emphasise advancing research to address sustainability challenges through transformative approaches. Key areas include fostering sectoral transitions via circular economies, strategic foresight, horizon scanning, and scenario planning, while prioritising societal challenges and enabling innovation aligned with environmental goals and inclusive growth.
- **Appropriation and dissemination:** The action roadmaps emphasise rapid knowledge dissemination through frameworks enabling research exploitation, Open Knowledge adoption, and inclusive SME participation. Priorities include advanced training in green technologies, digital transformation, foresight, and professional development for RMAs, fostering sustainability and collective accountability across diverse communities and stakeholders.

## R&I Futures: From Uncertainty to Policy Actions

The final section of this Working Paper highlights the transformative potential of Wild Cards analysis in shaping actionable and forward-looking R&I strategies. By synthesising insights from emerging technologies, disruptive innovations, and critical technologies, the analysis effectively bridges visionary foresight with operational impact, offering Europe a structured roadmap to optimise its innovation capabilities.

Emerging technologies, such as fusion reactors, solid-state batteries, and AI-powered ecological platforms, illustrate Europe's ability to address sustainability and resilience imperatives. For instance, smart grid systems exemplify decentralised energy innovation by fostering regional autonomy and supporting scalable transnational solutions. Actions such as piloting IoT-enabled microgrids within green tech hubs advance these goals, enhancing energy resilience and bolstering innovation ecosystems.

Disruptive innovations address critical societal challenges, including governance, migration, and environmental restoration. Adaptive City Design Models offer scalable housing and inclusive infrastructure for climate-displaced populations, while Participatory Governance Models embed inclusivity into decision-making, empowering communities to drive innovation. Foresight tools and inclusive funding ensure these initiatives foster societal harmony, adaptability, and resilience against global challenges.

Critical technologies accelerate Europe's ambitions for sustainability, competitiveness, and resilience. AI-driven advanced analytics enable data-informed governance, with tools like policy simulation AI aligning fragmented governance landscapes with cohesive strategies. Carbon capture technologies linked to nature-based solutions incentivise resource efficiency through transparent market mechanisms, embedding accountability into sustainability efforts.

This analysis draws on the European Commission Expert Group on the Interim Evaluation of Horizon Europe and two pivotal position papers from ManuFuture ETP, EIT Manufacturing KIC, EFFRA, and IZTECH. Their emphasis on integrating advanced manufacturing with circular economy frameworks and fostering biodiversity restoration highlights the interconnected nature of R&I priorities. Dynamic habitat zones, global biodiversity banks, and circular production models show how economic incentives drive environmental sustainability. By incorporating dual-use R&I approaches bridging civilian and defence applications, Europe can strengthen strategic autonomy and resilience while leveraging collaborative global partnerships. These synergies enable comprehensive responses to challenges like climate adaptation, resource efficiency, and technological sovereignty.

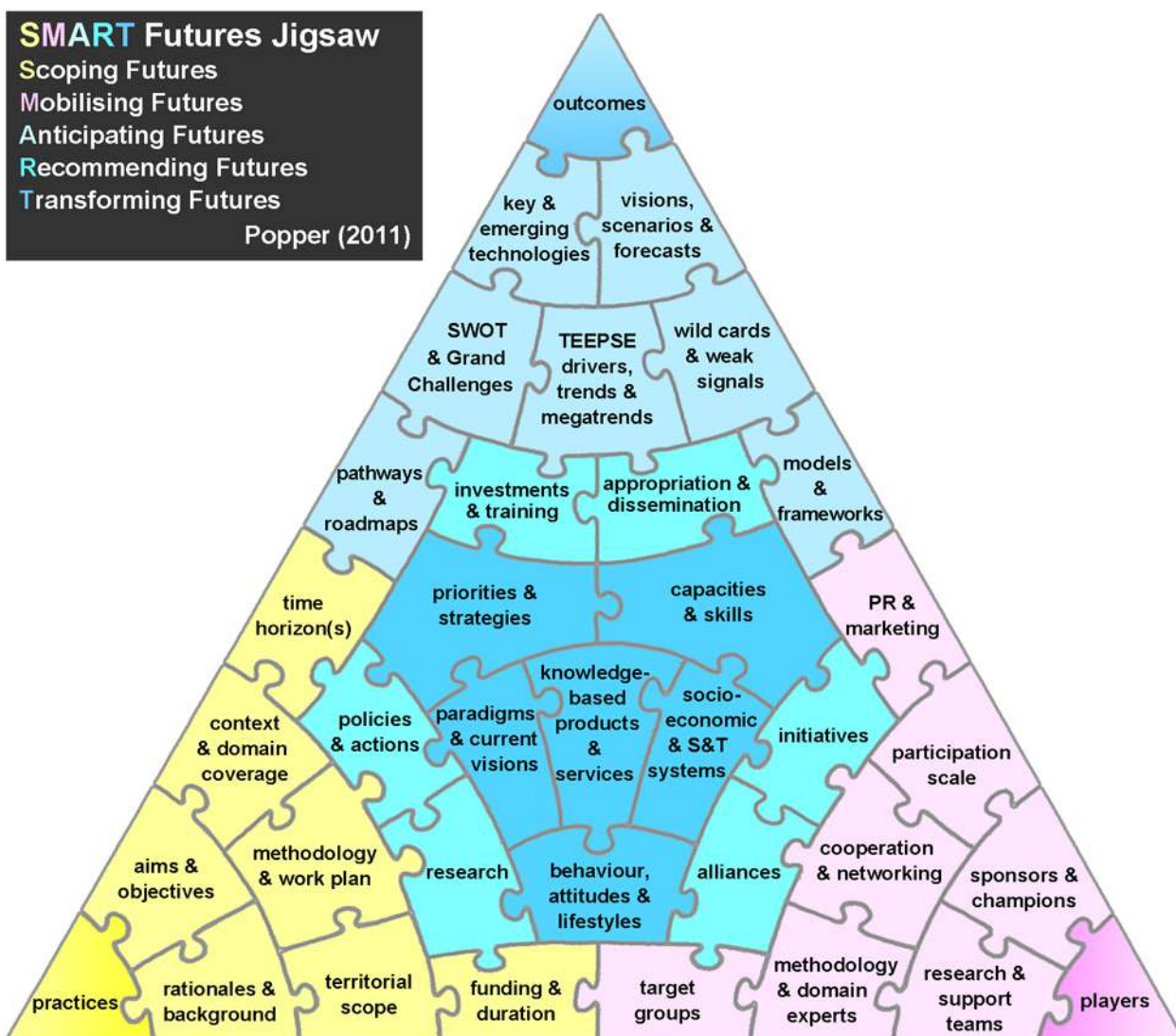
Translating these Wild Cards-inspired insights into strategic investments, decentralised systems, and inclusive actions equips Europe to navigate systemic challenges and capitalise on emerging opportunities. These coordinated pathways anchor the vision outlined in this CFI Working Paper on **'Action Roadmaps for More Resilient Research and Innovation Futures: Strategic Pathways to Foresight-Driven and Sustainable R&I Policies in FP10'**.



## Annexes

### The SMART Futures Jigsaw

The SMART Futures Jigsaw framework (Popper, 2011) provides a comprehensive structure for Foresight and Horizon Scanning (FHS) activities, encompassing 36 elements across five phases: **Scoping**, **Mobilising**, **Anticipating**, **Recommending**, and **Transforming**. These elements guide the design, implementation, and impact of FHS processes, including defining objectives, engaging stakeholders, exploring future scenarios, recommending policies, and fostering systemic transformations. By bridging boundaries between Foresight and Horizon Scanning, the framework ensures strategic alignment, actionable insights, and long-term renewal of priorities, capacities, and behaviours in addressing complex challenges and opportunities.



## Action Roadmapping (AR) Approach

**Action Roadmapping (AR)** is a structured methodology designed to guide the creation of coherent and interconnected actions across three levels – Strategic, Tactical, and Operational – to achieve innovation goals. Developed under the EU-funded CASI project (Popper et al., 2017, 2020), AR focuses on four critical dimensions of innovation: Context, People, Process, and Impact. Each dimension is further refined into 10 key aspects of sustainable innovation governance: *Momentum*, *Foresight*, *Resources*, *Mobilisation*, *Aptitude*, *Attitude*, *Catalysts*, *Fosterers*, *Transformation*, and *Sustainability*.

In this **CFI Working Paper**, the AR methodology informed the creation of five complementary R&I Action Roadmaps addressing Grand Challenges, Grand Opportunities, Interim Horizon Europe Needs, Manufacturing Needs, and Widening Needs. These roadmaps integrate 50 policy actions distributed across the three levels: 10 strategic, 15 tactical, and 25 operational actions.

**Strategic actions**, defined by top-level decision-makers, focus on setting long-term goals and priorities. Examples include:

- Mobilising political leadership to inspire sustainability-driven action.
- Facilitating systemic transformations through circular economies and governance integration.

**Tactical actions** translate strategic objectives into mid-level interventions, such as funding mechanisms, partnerships, and platforms. Examples include:

- Establishing strategic foresight mechanisms to align R&I investments with evolving challenges.
- Strengthening EU-wide innovation ecosystems through regional platforms and collaboration initiatives.

**Operational actions** are implemented by practitioners, focusing on execution and measurable results. Examples include:

- Scaling decentralised green technology pilots and fostering community-led biodiversity initiatives.
- Embedding circular economy principles into R&I policies to achieve sustainability.

The AR approach ensures balance and interconnectedness across strategic, tactical, and operational actions, addressing each key aspect proportionally: *Momentum* and *Transformation* dominate the strategic level, reflecting high-level systemic priorities; *Foresight*, *Resources*, and *Fosterers* are prominent in tactical actions, enabling mid-term implementation; while *Sustainability*, *Mobilisation*, and *Catalysts* shape operational actions, driving localised impact.

## Reflections on Foresight Expert Workshop in Brussels

The expert workshop in Brussels inspired wild cards by probing *Fractured Futures* and *Converging Horizons*, highlighting geopolitical shifts, technological disruptions, and citizen-led governance. These insights unveiled transformative possibilities, reshaping resilience narratives through collaborative foresight and innovative scenario-building exercises.

### Wild Cards and Weak Signals Analysis

The emergence of wild cards and associated weak signals may significantly impact and redefine the research and innovation landscape under these **Frontier Visions**.

Wild Cards	Weak Signals
<p><b>Finland's Golden Gateway:</b> Finland re-emerges as a global economic and geopolitical power, evoking its Nokia-driven golden era by leveraging its position as NATO's easternmost member and link between the EU and Russia. Normalized EU-Russia relations transform Finland into a hub for trade, energy, and security, reshaping Europe's landscape. Finland's ascent drives alliances, shifts dynamics, cementing its role as a key innovation corridor.</p>	<p>Major infrastructure and energy upgrades, including ports, railways, and a shift to U.S. nuclear fuel, boost Finland's strategic role.</p> <p>NATO membership without a referendum and Google's €27M data centre investment signal Finland's rising influence and innovation.</p>
<p><b>GCC-inspired Governance in Europe:</b> An EU country (e.g. Hungary) adopts a governance model inspired by the Gulf Cooperation Council (GCC), emphasising state stewardship of critical infrastructure and resources while abolishing income taxes. This approach fosters economic growth and prosperity, drawing attention as other EU nations explore similar systems. The model highlights the appeal of pragmatic governance balancing state control with dynamism.</p>	<p>Political movements in Central Europe advocating for resource nationalisation and streamlined taxation as drivers of growth.</p> <p>Growing public acceptance of state oversight in industries in return for economic advantages.</p>
<p><b>Citizen-Led Democratic Transformations:</b> A surge in citizen-led movements redefines democratic systems. Bottom-up governance, powered by participatory assemblies and blockchain-based direct democracy, replaces traditional hierarchies. Hyper-local decision-making emerges, fostering inclusivity but creating fragmented, volatile and chaotic political landscapes in Europe.</p>	<p>Proliferation of grassroots movements advocating for participatory governance and policy co-creation.</p> <p>Development of blockchain-based voting and decision-making platforms gaining traction among citizens.</p>
<p><b>Radical Innovation in AI or Synthetic Biology:</b> A breakthrough in AI or synthetic biology disrupts global labour markets and societal structures. Fully autonomous systems replace entire sectors of human labour, and synthetic biology enables the creation of new materials, food sources, and medical treatments. This fuels inequality and ethical debates while boosting unprecedented innovation.</p>	<p>Accelerated R&amp;D investments in synthetic biology for agriculture and healthcare.</p> <p>Emerging trends in fully automated factories and logistics chains replacing human workers.</p>
<p><b>Breakthrough in Energy Storage/Production:</b> A transformative energy breakthrough—such as affordable fusion energy or ultra-efficient batteries—shifts global geopolitical power. Fossil fuel-dependent economies collapse, while renewable-energy innovators become dominant. This accelerates the green transition but destabilizes regions reliant on traditional energy exports.</p>	<p>Reports of experimental success in high-yield energy storage or fusion technologies.</p> <p>Declining investments in fossil fuel industries as renewables achieve cost parity.</p>

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## Disclaimer

The ideas presented in this CFI Working Paper represent solely the views of the authors. They do not reflect any endorsement by the European Commission, or by the organisations and experts participating in the various activities that have inspired this work. This Working Paper has also benefited from the use of advanced AI tools for final proofreading and image enhancement. However, the content and conclusions presented were independently developed through the comprehensive activities detailed in the introduction, as well as informed by expert feedback acknowledged in this document. AI was utilised exclusively to assist with editorial refinement and the presentation of the material.

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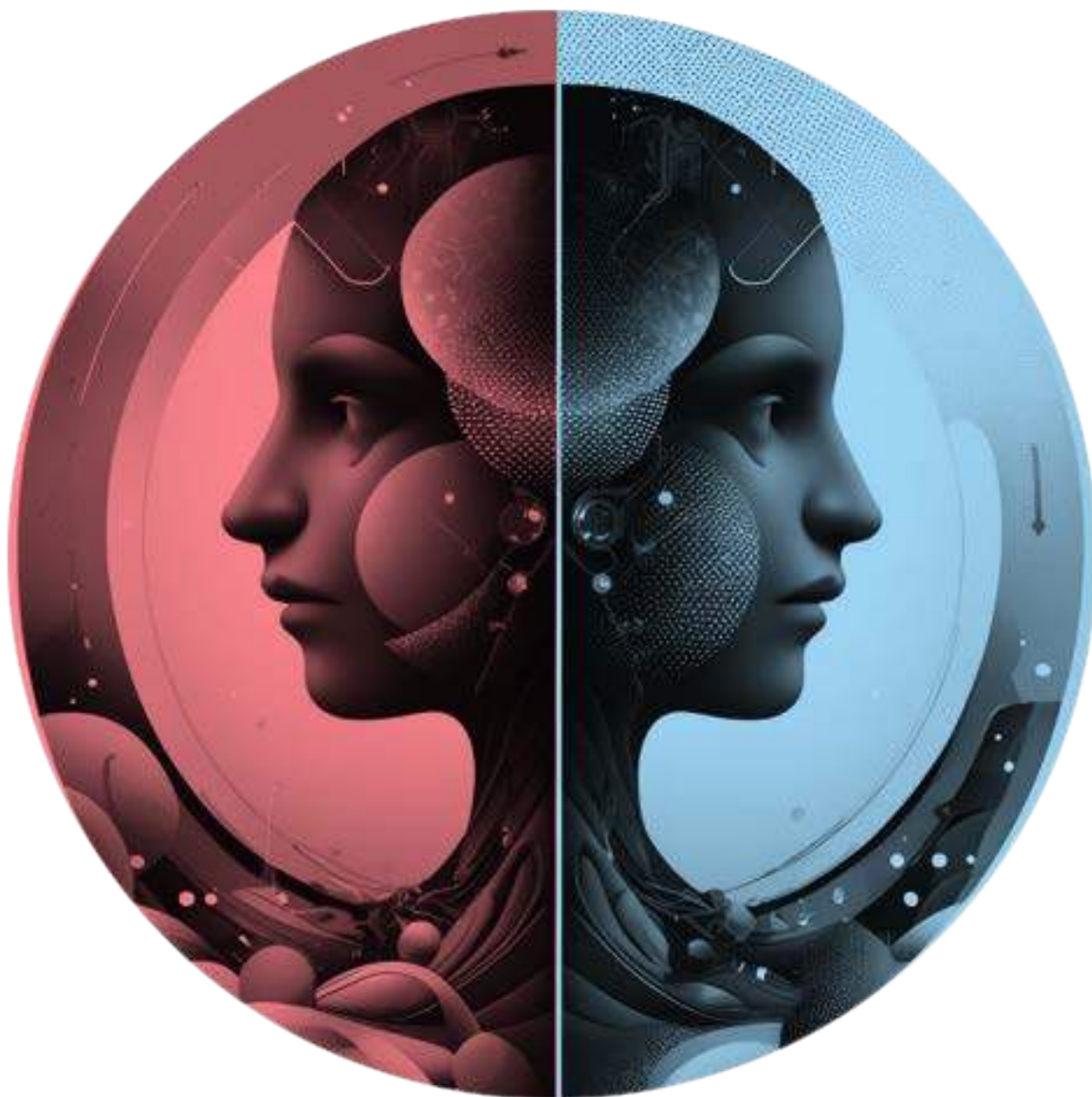
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# **ACTION ROADMAPS**

## **FUTURES THINKING APPLIED**