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Strategic priority-setting in research in times of crisis: how to optimise decision-making for societal resilience

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Review and advisory input was provided by Dr. Alan Paic, Senior Policy Analyst at the Science and Technology Policy (STP) Division of the OECD Directorate for Science, Technology and Innovation (STI).

Authors:
Pavel Gol’din *http://orcid.org/0000-0001-6118-1384*
Oleksiy Kolezhuk *https://orcid.org/0000-0002-9739-0986*
Vitaliy Omelyanenko *https://orcid.org/0000-0003-0713-1444*
Anna Vorontsova *https://orcid.org/0000-0003-0603-3869*
Svitlana Tarasenko *https://orcid.org/0000-0002-4829-0559*

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Summary

Ukraine's research system is operating under conditions of exceptional stress, shaped by war, large-scale destruction, depopulation, and economic constraints. In such contexts, conventional approaches to research priority setting normally designed for stability, incremental change, and long consultation cycles cannot be fully applied and they need some modification to gain proper flexibility and openness to unexpected changes and challenges. This analytical report addresses a critical policy challenge: how to set strategic research priorities during existential crises in a way that supports immediate societal needs while safeguarding long-term national resilience and development. Further, the Ukraine-centered context of our analysis implies specific goals, including post-war reconstruction, rapid technological and environmental changes, as well as the overall imperative vector of national development towards the European integration with its philosophy driven by mission-oriented innovation and competitiveness.

Our study focuses on research priority setting, reflecting the separation of research and innovation processes under Ukrainian legislation and policy. Given the acute resource constraints, linking research priorities to societal challenges and recovery needs is essential to rebuilding trust and legitimising public spending, while focus should still remain on the country's broader development needs including excellent basic science, advanced technology, and regional development. The analytical framework is designed to extend to the broader innovation ecosystem once the relevant policies are in place. The general principle of our approach is suggesting flexible analytical tools which can be applied in conditions of high uncertainty, rapidly changing context and limited human, financial and other resources.

Drawing on an analysis of past experience of several countries which may serve as relevant examples for comparison, including countries affected by war, long-term security threats, post-war reconstruction, and systemic transformation, we present the context as a four-stage framework reflecting how the objectives of research and innovation policy evolve under wartime conditions, reconstruction needs, economic restructuring and long-term societal challenges. As seen from real world situations, while analytically distinct, the stages may significantly overlap in practice.

Our study identifies a two-tier priority-setting framework, combining international multi-criteria assessment practices with EU foresight approaches. On the first tier, research areas are mapped to national grand challenges (or, from an alternative perspective, opportunities). These classes include basic needs: overcoming the consequences of war, post-war reconstruction, energy and food security, health, environment and climate change, culture and national identity, economy, education, governance and justice,

defence and security, and also development needs which are considered as equal to grand challenges or opportunities for our operational aim: advanced technologies, excellency in basic science and regional development. Eight missions are proposed on this basis. This structure links scientific directions to fundamental societal needs. On the second tier, each research area is assessed using six quantitative indicators: strategic significance for national defence and dual-use potential; economic and recovery impact; social impact including quality of life and social cohesion; human dimension: assessment of the readiness of existing human capital and research teams; implementation feasibility, and EU alignment, based on a four-point scale, providing transparent differentiation of priorities.

The aggregated results are visualized in a Priority Graph (Impact × Readiness), which distinguishes areas ready for immediate implementation ("Quick Wins") from those requiring capacity building ("Strategic Bets"). Additionally, all directions undergo a driver stress-test, assessing their resilience to global and Ukraine-specific risks. This procedure helps determine whether a priority will remain relevant under unpredictable changes, from new pandemic threats to risks facing the energy system.

To ensure practical implementation, we suggest a blueprint of a possible nine-month foresight process, taking Ukraine as the example, which can be used as a part of framework conditions or an exercise in real life. This plan includes desk research, two Delphi rounds, international expert engagement, validation, and the preparation of eight mission-specific roadmaps. This stepwise structure allows for both analytical depth and broad stakeholder participation. Seven countries (Estonia, Finland, Denmark, the United Kingdom, Norway, Sweden and Netherlands) are suggested among the optimal international partners due to their relevant experience in digital transformation, mission-oriented innovation, reconstruction, and research excellence.

The expected outcome of the process is the identification of 40-60 priority research areas. The roadmaps for each mission should outline realistic implementation plans through 2035, funding opportunities, including EU co-funding, risk assessments, indicators, and institutional mechanisms. They should also include quality control, post-project monitoring, reassessment, and provisions for potential adjustments. Overall, the proposed framework provides Ukraine with a flexible approach to setting scientific priorities in crisis conditions. It supports the modernisation of the national research system, increases efficiency of resource use, and aligns Ukraine's research priority-setting with European practices during wartime and throughout post-war reconstruction.

Introduction

Present-day research and innovation systems are confronted with multiple and interlocking crises. Wars, pandemics, energy shocks, rapid AI development, digital security threats, and accelerating climate change have transformed the environment in which research policy operates. Under such conditions, traditional mechanisms of strategic planning and priority-setting often become insufficient, as they are designed for stability rather than volatility, for incremental change rather than existential disruption. As a result, national research systems face the dual challenge of responding to immediate societal threats while simultaneously preserving their long-term capacity for resilience, development, and international integration.

These pressures are particularly acute for countries experiencing protracted or multifaceted crises, such as Ukraine, whose science system must function under conditions of war, reconstruction needs, economic restructuring, demographic changes (due to war losses, birth rate fall and emigration), and requirements and commitment related to European integration. The wartime and post-war context amplify the need for a new generation of priority-setting frameworks—ones that are adaptive, mission-driven, inclusive, and capable of balancing urgent needs with strategic, future-oriented development.

However, while navigating the intensity of these challenges, Ukraine does not yet possess a coherent, crisis-adaptive system for research priority-setting, and this creates a strategic gap between urgent societal needs and existing policies.[1] This problem forms the core motivation for this study.

Against this background, the present study has the following objectives:

- to analyse international experience in prioritizing research directions through a comparative case study of selected countries;
- to develop a framework for strategic priority setting in research systems during existential crises that optimizes both immediate crisis response and long-term societal resilience;
- to provide the methodology of strategic

[1] Ideally, Ukraine would develop a Crisis-Adaptive Research and Innovation (R&I) System.
For the aim of this study, a crisis-adaptive research and innovation (R&I) system may be defined as a system designed to operate effectively under conditions of severe, persistent, and overlapping shocks, such as war, pandemics, energy crises, climate extremes, or systemic economic disruption. It combines institutional stability with strategic flexibility: preserving long-term scientific excellence and knowledge production while enabling the rapid reorientation of priorities, funding instruments, and governance arrangements toward urgent societal missions. A crisis-adaptive R&I system integrates short- and medium-term planning horizons, applies stress-tested and evidence-based priority-setting, and allows for timely reallocation of resources without undermining research integrity or capacity. Rather than seeking to predict crises, such a system is built to absorb shocks and learn dynamically under conditions of high uncertainty. – Definition by Alan Paic

priority-setting in research during crises and to test it for Ukraine's environment;
- to analyze and conceptualize the mechanisms for determining scientific priorities in crisis conditions (primarily exemplified here by the war and related context for Ukraine);
- to develop a framework for adaptive and resilient research policy that ensures the relevance, inclusiveness and sustainability of research priorities in times of instability.

Accordingly, the study is guided by the following key research question: "How can research systems optimize strategic priority setting during existential crises to maximize both immediate societal needs fulfilment and long-term resilience capacity?"

The study focuses on research priority setting reflecting current Ukrainian legislation, where research and innovation are treated as distinct processes governed by separate funding instruments and regulatory regimes. Given the acute resource scarcity and war related existential crisis, research expenditure demands clear justification for policymakers, politicians, and society. Therefore, explicitly connecting research priorities to societal challenges and recovery needs is essential to rebuilding trust and legitimising public spending. However, the development needs, including excellent basic science including curiosity-driven research, development of new technologies and regional development with regard to diversity in local conditions, should also be focused on. Nonetheless, the analytical framework is designed with the flexibility to be extended to a more systemic approach comprising the entire research and innovation ecosystem, addressing complex structural challenges, once the policies are in place.

The study is based on a mixed methods research design combining desk research, qualitative expert input, and quantitative analytical techniques. At the first stage, a desk study was conducted using international and national strategic documents, policy papers, statistical databases, academic publications, and analytical reports. Desk research was also used to construct a system of indicators and to perform a structured comparative analysis of selected countries, enabling cross-country comparison of:

- prioritization mechanisms, assessing the alignment between strategic planning and public demand, including the evolution of research agenda;
- implementation frameworks, focusing on policy instruments that facilitate the transformation of research ideas into market-ready products, including funding models and infrastructure development;
- impact indicators, providing a quantitative measurement of scientific and economic outcomes through the analysis of innovation performance, publication activity, and patenting;
- resilience to crises, examining the adaptation mechanisms and policy responses of research systems to global shocks, such as the COVID-19 pandemic and financial crises.

Building on these findings, a methodological multi-criterial framework was developed that integrates multi-level priority setting practices with EU foresight approaches and the Ukrainian context as a model for developing excellent research under crisis conditions under an uncertain time period (Section 2). In particular, our framework draws on a three level (descriptor, qualifier, and indicator based) model adopted from some of the EU directives applied to mission-oriented research funding and technology foresight, including multi-criteria evaluation approaches applied in international practice, e.g., in the EU mission based planning, with modifications relevant for the Ukrainian context as an example of a crisis driven development. The content of the framework was based on the PESTLE (political, economic, social, technological, legal, and environmental) analytical approach adopted from strategic management, with the correction concerning relevant Ukrainian context details and conditions. The proposed framework was further validated through a focused expert discussion conducted in the format of a focus group of six experts.

The final stage involved synthesis of findings and preparation of the case which could serve as an example for a crisis-driven foresight of research priorities based on the current situation of Ukraine in war (Section 3). The AI (Claude Sonnet 4.6) assisted the design of the case based on scenario modelling, with the following input data:

- the abovementioned two-tiered three level framework with the local context related, PESTLE relevant details;
- Ukrainian legal and regulatory environment, including the relevant laws and strategies (government documents) listed in the Section 3;
- content and findings of the desk research and other relevant references, including the descriptions and discussions of foresights on establishing research priorities in Czechia, Denmark, Estonia, Finland, Netherlands, South Korea, and other countries, as well as the OECD foresight toolkit;
- content preconditions: alignment with EU framework programmes with a view to joint development; focus on green development, digital development, societal resilience; focus on areas broadly characterised as “Quality of Life” (healthcare, environment, post-war recovery), and established and prospective bilateral international partnerships; and constraints (necessity to follow requirements of statistical significance of samples for surveys; realistically low available budget of 400 000 Euro; and a 9 month duration).

From the initial seven primary (simple) scenario-based foresight designs selected for their originality and relevance to the Ukrainian context, multi-variable hybrid models were constructed by combining two to four options each. Following this synthesis, the top eight best hybrid designs were isolated. Based on these configurations, three complex frameworks were developed, from which two final candidates were selected and manually integrated. Through structured expert discussion and consensus, uncertain operational parameters were adjusted and corrected, resulting in the single consensus design presented herein.

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SECTION 1. COMPARATIVE ANALYSIS OF INTERNATIONAL EXPERIENCE IN DETERMINING AND IMPLEMENTING SCIENTIFIC RESEARCH PRIORITIES

The prioritisation of research directions is a tool for strategic management of societal development. The effectiveness of national research and innovation systems largely depends on the ability of governments to form well-founded research priorities and ensure their consistency with the needs of the economy and society (Ranga & Kim, 2023; UNCTAD - Strengthening; Nelson, 1993).

At the same time, recent research shows that priority setting itself changes fundamentally under crisis conditions. When time is compressed, uncertainty is high, and the research system is under strain, the effect is that governments cannot rely on traditional consultation cycles or incremental adjustments. Instead, they must rapidly determine which problems require central direction, which scientific capacities must be shielded from collapse, and which investments can serve both immediate crisis response and long-term recovery (Gross & Sampat, 2022a; Reale, 2021; Hynes et al., 2020).

Approaches to the formation and implementation of research priorities differ significantly depending on the historical experience of research in a country, institutional architecture, the level of economic development, and the level of integration of the country into global research and innovation networks. That is why a comparative analysis of international experience allows us to identify both universal patterns and specific models that can inform Ukraine's national context.

Given this diversity of models and the profound effect that crises have on priority-setting mechanisms, it becomes essential to apply a structured analytical approach that captures how research objectives evolve under different stages of instability, recovery, and long-term transformation.

Analytical Framework: Four Stages of Research Priority Setting in Crisis and Recovery

To ensure analytical relevance for Ukraine, this section applies a four-stage framework reflecting on how the objectives of research and innovation policy evolve under wartime conditions, reconstruction needs, economic restructuring, and long-term societal challenges. While analytically distinct, the stages may overlap in practice (as already seen in Ukraine).

Stage 1: Emergency Mode – Research for Security and Survival

At this stage, the overriding objective is national survival under conditions of acute security threat. Priority setting is dominated by defence related research and development, dual-use technologies, cybersecurity, rapid problem solving capacities, and the protection of critical infrastructure. In such conditions, scientific priorities are defined less by long-term disciplinary agendas than by immediate operational needs, strategic vulnerabilities, and the state's capacity to mobilise knowledge for wartime response (Gross & Sampat, 2022a, b). Decision-making is typically centralised, funding procedures are accelerated, and science is closely integrated with defence and security policy.

Relevant international experience includes countries operating under long-term security pressure. For example, the military context in Israel poses constraints on the research environment. Scientific priorities in Israel during wartime are determined through interagency missions, integrating security, resilience, defence, rehabilitation, and applied AI (OECD, 2025). The Israeli government's documents directly mention post-conflict infrastructure reconstruction, treatment and rehabilitation of veterans and civilians, including mental health, as significant additional budgetary needs. Scientific priority is determined not only academically, but through the joint work of ministries, the defence bloc, and innovation institutions around specific national tasks.

In Croatia in 1995, the logic was different in form but similar in essence. During the 1991–1995 war, the state primarily tried to preserve the research itself. The OECD (2014) describes the period 1991–1993 as a time of economic decline, transition to the market, and survival of the research system. Despite the 1991–1995 war, Croatia has maintained the activities of all the universities and scientific institutes as well as its involvement in regional and international projects.

South Korea provides a particularly instructive case of how sustained security pressure organises research priority setting over the long term. Following the Korean War (1950-1953), the country faced an enduring threat from North Korea that has continuously structured its research and innovation priorities around defence and technological sovereignty. As early as 1954, the government established the Ministry of National Defence Scientific Research Institute to foster independent defence production capabilities, and in 1970 President Park Chung-hee created the Agency for Defence Development (ADD) as a centralised government body modelled on the US Defence Advanced Research Projects Agency to develop source technologies for the military (Carnegie Endowment, 2026).

This vertically integrated model, in which the ADD develops core technologies and transfers them to private companies for production, enabled active mobilisation of research resources around security-defined missions. In more recent decades, South Korea's defence research governance has evolved under successive initiatives, for example, Defence Innovation 4.0 (2023), which prioritises AI, unmanned systems and dual-use technologies. The government has also adopted the National Strategic Technology Nurture Plan covering twelve priority areas including advanced semiconductors, robotics, and AI (ORF, 2025; Lowy Institute, 2025).

Countries such as China and Türkiye demonstrate how strong centralisation of scientific priority setting, rapid mobilisation of research and development (R&D) resources and concentrated investments in defence technologies, dual-use innovation, and cybersecurity can generate technological solutions critical to national survival (Groenewegen-Lau & Laha, 2023; Mohydin, 2024; Li, 2026). Although these countries are not direct wartime analogues for Ukraine, they illustrate institutional arrangements characteristic of security-driven research systems: accelerated decision-making, vertically integrated research governance, and mission-oriented programmes targeting technological sovereignty. These mechanisms echo the broader international logic seen in states such as Israel, South Korea, Finland, and Estonia, where long-term exposure to security pressures fostered rapid deployment problem-solving capabilities and defence-aligned innovation ecosystems (OECD, 2026). In the Ukrainian context, this phase underscores the need to strengthen defence R&D, secure digital infrastructure, and consolidate national research capabilities to support wartime resilience.

Stage 2: Post-War Reconstruction – Mission-Oriented Mobilisation

Following stabilisation, research priorities shift toward rebuilding physical and digital infrastructure, restoring scientific institutions, ensuring energy security, addressing environmental damage, demining, and renewing industrial capacity. Mission-oriented approaches become central, allowing governments to mobilise science and technology around clearly defined reconstruction objectives.

The historical trajectories of Germany, the United Kingdom, the Netherlands and Italy most closely reflect this stage, whose post-war recovery was deeply intertwined with the reconstruction of scientific institutions and industrial capacity. In all four cases, post-war recovery was not limited to the physical reconstruction of the economy. It also involved the reorganisation of scientific institutions, the rebuilding of research capacity, the restoration or redesign of state-industry-science relations, and the use of science and technology policy as an instrument of national recovery and modernization. In West Germany, post-war reconstruction was closely tied to the reconstitution of scientific governance under occupation and to the rebuilding of research organisations as part of broader economic and political stabilization (Beyler & Low, 2003). In the United Kingdom, post-war planning linked civil research policy to industrial reconstruction, productivity growth, and the expansion of industrial R&D, even if implementation remained constrained by resources and administrative limits (Cairncross, 1996, Horrocks, 1999). In the Netherlands, reconstruction was intertwined with the reorganisation of scientific research and the creation of new funding structures that gave science a more explicit place in national recovery and technological development (Brookman, 1983). In Italy, post-war recovery similarly combined industrial reconstruction with state-led development, technology transfer, and later reforms in education and research capacity that supported longer-term innovation and modernization (Zamagni, 1986). Taken together, these cases suggest that post-war reconstruction should be understood not simply as rebuilding damaged infrastructure, but as a phase in which governments mobilise research, innovation, and institutional reform to restore productive capacity and shape a new developmental trajectory.

Their experience resonates with post-war recovery models such as Croatia's post-1995 transformation. In the National Research Program 1996–2000, the priorities have already been included: biomedicine and healthcare, ICT, defence, reconstruction and development of infrastructure, especially in the newly liberated territories, as well as agriculture, forestry, energy, environment, and demographic research. The National Science and Research Programme (1996-2000) listed a number of general and special research priorities, implemented within the framework of six scientific fields: natural sciences, technical sciences, biomedicine, biotechnology, social sciences, and humanities. However, the Programme has never been fully implemented. In Croatia the practice of setting numerous priorities showed that priorities should be redefined in a more systematic manner than it has been done there (European Commission, 2004).

The South Korean case adds a particularly well-documented trajectory of post-war reconstruction through science and technology policy. Following the devastation of the Korean War, South Korea in the 1950s was among the world's poorest economies and an overwhelmingly agrarian structure (Chung, 2007; Park, 2019). Post-war reconstruction in the 1950s relied heavily on US foreign aid primarily directed at restoring infrastructure in energy, communications, transportation, education, and health (Park, 2019), as it had in other countries at that time.

The turning point came with the First Five-Year Economic Development Plan (1962-1966), which integrated science and technology policy into national economic planning and established the Korea Institute of Science and Technology (KIST) in 1966 as the country's first modern public research institute, followed by the Ministry of Science and Technology in 1967 (Campbell, 2016; Jung & Mah, 2013). Throughout the 1960s and 1970s, the government maintained centralised control over R&D priority-setting, directing resources toward heavy and chemical industries, building public research institutes, and investing in technical education (Jung & Mah, 2013; Chung, 2007). This is a model in which the state assumes full responsibility for initial research capacity-building and then gradually shifts to a facilitative role (managing directions of private investments in priority sectors).

For Ukraine, this phase implies that research priorities must become an instrument of reconstruction, supporting demining technologies (which already show rapid ongoing development in Ukraine), green energy transition, industrial revitalisation, and the rebuilding of research infrastructure damaged or weakened during the war in different scenarios where different ways are possible for defining research priorities. It is important to note that most research priorities-setting consist of a testing process that includes 2 components: main research directions that have no tendency to change, and a set of research directions that are flexible.

Stage 3: Innovation Driven Competitiveness

As reconstruction progresses, priority setting increasingly targets technological upgrading, productivity growth, development of high value added industries, and (re-)integration into regional and global value chains. At this stage, competitiveness becomes a core policy objective, requiring systematic coordination of research policy, industrial policy, and human capital development (Paic & Viros, 2019; Larrue, 2021).

As an example, the long-term development trajectories of Estonia, Finland, and Sweden demonstrate how, once reconstruction is complete, the strategic goal of research policy shifts toward building a competitive, technology-intensive economy with strong global linkages. Estonia reflects a model, characterized by a highly digitalized and agile national innovation system, where strong coordination between government, universities, and internationally oriented firms underpins technological development and global integration (European Commission, 2025; OECD, 2025). The Estonian approach emphasizes e-governance, startup ecosystems, and flexible institutional frameworks, enabling rapid adaptation to technological change and fostering innovation-driven growth (e.g., through initiatives like Startup Estonia). The Finnish case is often used as an example of how high-level coordination can support the transition toward a knowledge-based and internationally competitive economy (Lemola, 2001; Galabova, 2012). Sweden reflects a somewhat different model, based more on a strong national innovation system with internationally oriented firms, universities, and distributed governance structures that support technological development and global economic integration (Chaminade et al., 2010). In these cases, the strategic emphasis moves toward advanced industry, research capacity, innovation infrastructure, and the formation of globally connected high-technology sectors.

In South Korea, government research institutes played a central role in absorbing and diffusing imported technologies during the 1960s, supporting heavy and chemical industries and enabling the emergence of large industrial conglomerates (Jung & Mah, 2013; UNIDO, 2016). The government pushed industrial conglomerates to invest heavily in R&D while shielding them from competition, and with increased R&D intensity focused on applied knowledge, firms such as LG and Samsung were driven toward new heavy industries, including petrochemicals, car manufacturing, shipbuilding and consumer electronics. At the systemic level, South Korea developed a comprehensive and centralised governance structure built around foresight-based mid- and long-term planning, with the National Science and Technology Council assuming responsibility for setting strategic research and innovation (R&I) directions across government (Belfer, 2025; OECD, 2023). TheKorean history somewhat correlates with the recent Ukrainian practice of setting stable research priorities during the last 20 years.

Stage 4: Long-Term Societal Resilience

At the most advanced stage, research priorities focus on addressing complex societal challenges—public health, demographic change, climate adaptation, environmental recovery, and inclusive development—through mission-oriented and challenge-driven frameworks. Science and innovation function as pillars of societal resilience and long-term well-being (Janssen et al., 2021).

This pattern is most clearly associated with the Nordic countries, especially Finland and Sweden, and is also visible in the Netherlands and in the evolving European Union mission framework (Fagerberg & Hutschenreiter, 2020; Giacometti & Jessen, 2024). Finland's resilience-oriented and transformative policies, Sweden's societal-challenge and system-innovation programmes, and broader Nordic experimentation with transformative innovation policy illustrate how science and innovation can be used as instruments of long-term adaptation and public value creation rather than only economic growth. Related tendencies can also be observed in Norway and the United Kingdom, particularly in policy domains framed around grand challenges and transition management (Upham et al., 2016).

For Ukraine, this final phase implies the transition from crisis-oriented and reconstruction-driven research policy toward a mature system capable of supporting long-term societal goals—from managing consequences of population decrease and birth rate drop to environmental regeneration and climate resilience.

Taken together, these four stages provide a conceptual framework grounded largely in retrospective experience: Stages 1 and 2 draw on historical trajectories of countries that have navigated war, systemic disruption or post-war reconstruction. By contrast, the core analytical focus of this section lies in Stages 3 and 4, which correspond to contemporary research systems and current policy practices:

- **Germany, the United Kingdom, the Netherlands** and **Italy** exemplify post-war reconstruction of scientific and industrial capacity (Edler and Fagerberg, 2017; OECD, 2025);

- **Finland** and **Sweden** demonstrate an approach to determining the directions of scientific development, formed in the conditions of their territorial remoteness from central Europe, which led to lower military losses in World War II and contributed to the formation of specific models of determining scientific priorities (European Commission: Directorate-General, 2025; Kreutzer and Taalbi, 2026);

- **Estonia** presents relevant experience for Ukraine of effective restructuring of the economy, scientific priorities in interaction with business, after leaving the Soviet Union (Kalvet, 2012; European Commission, 2025; OECD, 2025);

- **China** and **Türkiye** represent highly centralised systems of priority-setting and successful "technological leap" models (European Commission, 2025; OECD, 2025; Maddi et al., 2025; Zheng and Guo, 2019).

This configuration allows for an examination of universal principles and context-specific mechanisms of research priority setting, as well as their applicability for Ukraine's wartime and post-war development needs.

Below we discuss modern mechanisms of priority setting, implementation tools, impact indicators, and crisis response approaches used today in the countries selected for comparative analysis.

Prioritization: From Strategic Plan to Public Demand

The identification of research priorities is one of the key instruments for shaping an effective state science and technology policy. It is through this process that the development of science is aligned with the needs of the economy, society, and global challenges. Under conditions of uncertainty, technological competition, and the need for post-crisis and post-war recovery, the issue of selecting scientific priorities becomes particularly significant and transforms from a purely administrative procedure into a complex, multi-level process of strategic governance.

Yet any comprehensive framework for research priority-setting must also account for the enduring importance of basic research driven by scientific curiosity. Leading innovation systems, including those of the United States, Germany, and the Nordic countries, have long maintained a deliberate balance between targeted, problem-oriented R&D and open-ended investigator-led research, recognising that an exclusive focus on short-term priorities risks eroding the foundational scientific capacity on which future innovation depends (Lepori et al., 2007). For post-conflict economies in particular, neglect of basic research carries a compounded risk: it narrows the scientific gene pool, weakens university research cultures, and reduces the long-term absorptive capacity needed to benefit from international knowledge flows.

International practice demonstrates substantial variability in approaches to setting priorities. This diversity is driven by the institutional characteristics of countries, the level of development of national innovation systems, governance systems and models, the models of interaction between the state, business, and the academic community, as well as the prevailing societal demands. Hybrid models, combining centralized strategic vision with broad stakeholder engagement, foresight instruments, mission-oriented approaches, and co-creation mechanisms, are gaining increasing prominence (Ranga & Kim, 2023).

Analysis of the experience of the countries selected reveals not only different organizational models (from top-down to bottom-up), but also deeper distinctions in the logic of prioritization. In this context, a comparative analysis of approaches to defining research priorities across countries is particularly relevant, as it enables a systematic assessment of their advantages, limitations, and potential for implementation in other national settings. The following section is devoted to examining science prioritization models in selected countries.

- In **Germany**, research priorities are defined within several overarching national frameworks, including the Future Research and Innovation Strategy (Federal

Ministry of Education and Research, n.d.), the High-Tech Strategy (The High-Tech Strategy 2025 Progress Report, 2025), the Excellence Strategy (Federal Ministry of Research, Technology and Space, n.d.), all coordinated by the Federal Ministry of Education and Research (BMBF). Priority-setting combines a strategic top-down vision with structured expert participation through the Ministry's Advisory Council and Germany's major research organisations. The prioritisation process relies on inputs from autonomous scientific societies and research associations such as the Max Planck Society, Helmholtz Association, Leibniz Association, Fraunhofer Society, and the German Research Foundation (DFG). These organisations contribute analytical expertise, disciplinary roadmaps, and long-term research agendas, which inform federal strategic documents. Within the Excellence Strategy, thematic priorities emerge through competitive evaluation of Clusters of Excellence, assessed by DFG and the German Council of Science and Humanities. This mechanism acts as a national filter for identifying high-potential research fields, which subsequently influence national priority-setting cycles. Priority areas span natural sciences, engineering, medicine, social sciences, and humanities, reflecting both scientific excellence and societal needs.

- In **the United Kingdom**, strategic directions for science and technology development are set by the overarching UK Science and Technology Framework, aligned with the national ambition to transform the country into a "Science Superpower" by 2030. Implementation is coordinated by the Department for Science, Innovation and Technology (DSIT), together with the UK Research and Innovation (UKRI) holding and the specialised network of Catapult centres for applied innovation. The Advanced Research and Invention Agency (ARIA) was established to fund "high-risk, high-reward" research. The 2022 R&D Roadmap highlights the importance of "moonshot-type" projects—large, high-risk research initiatives with potentially significant technological or societal impact. Assessment of research proposals places strong emphasis on their impact across policies, standards, and societal innovations. In selecting and implementing research priorities, DSIT relies on priority lines developed by the Government based on foresight studies, horizon-scanning results, consultations, and dialogue with key stakeholders in the national research and innovation system (NIPO, 2026).

- In **the Netherlands**, the National Science Agenda (NWA) was initiated in 2015 by the government to ensure alignment between scientific development, societal challenges, and research priorities. The process followed a bottom-up approach that involved open consultations with researchers, policymakers, businesses, and the public. Nearly 12,000 questions were submitted, covering fundamental, societal, and applied issues. A Knowledge Coalition—comprising universities, research councils, national institutes, and employer federations—was established to process these submissions. All questions were reviewed by experts and consolidated into 140 cluster questions within 25 thematic areas, grouped into five overarching domains. The country also employs sectoral plans ("sectorplannen"), in which universities and the government jointly identify priority scientific profiles and receive targeted funding. For each sector, a monitoring committee conducts interim evaluations after three years (2026) and final evaluations after six years (2029) (NWO, n.d.; Technopolis Group, 2025).

- The mechanism for determining research priorities in **Finland** is based on a multi-level system in which the state plays a key role (most notably the Research and Innovation Council chaired by the

Prime Minister), while maintaining the institutional autonomy of implementing agencies and research organisations. The process begins with identifying global societal challenges (such as climate neutrality, digital security, or demographic ageing) and proceeds to selecting specific instruments for addressing them, including priority technological solutions (Finnish Government, 2025). Niche selection involves active engagement of business and academic communities through the flagship cluster mechanism (Finnish Flagships) (Sotarauta, 2024). Operational implementation is divided between Business Finland, which funds innovation-oriented business projects within chosen niches, and the state Technical Research Centre VTT, which provides an applied scientific base and technology transfer. These priorities are formalized through the Act on R&D Funding and the Multi-annual Plan for R&D Funding.

- The **Swedish** system of defining scientific priorities is characterised by a high degree of decentralisation. The government sets overall strategic directions, but decision-making is distributed among state agencies (Vinnova, Vetenskapsrådet, Formas, etc.), major industrial actors (Ericsson, Saab, Volvo), and autonomous universities. Science prioritisation follows a mission-oriented approach. Priorities are defined according to major global societal challenges framed within the new national initiative Impact Innovation (Grillitsch, 2024; Vinnova, 2024, 2025). Formal consolidation of these priorities occurs through the four-year Research Policy Bill, which ensures the regulatory and financial stability of the R&D sector.

- In **Italy**, strategic orientations for a research policy are formulated through national framework documents National Research Programme (PNR 2021–2027) and National Recovery and Resilience Plan (PNRR). The methodological approach to developing the PNR is based on co-design involving the scientific community and stakeholders, coordination among national and regional administrations, and consultations with various ministries. Expert commissions were established (more than 240 scholars in 28 working groups) to identify priority research areas (Ministero dell’Università e della Ricerca, 2021). Implementation of strategic goals is coordinated by the Ministry of Universities and Research (MUR) in close cooperation with major research institutions (Consiglio Nazionale delle Ricerche; ENEA; Istituto Italiano di Tecnologia), public investment instruments (Fondo Nazionale Innovazione / CDP Venture Capital), and a network of regional technopoles and science and technology centres. Italian research policy combines support for fundamental research with applied programmes (energy and digital transition, healthcare, industrial innovation), with significant PNRR resources directed toward R&D, technology transfer, and scaling research results for industrial application.

- In **Estonia**, priority “focus areas” are defined in the National Strategy for Research, Development, Innovation and Entrepreneurship (RDIE Strategy 2021–2035), which outlines long-term science and technology goals and links fundamental research to economic and societal needs. Implementation is coordinated by the Ministry of Education and Research in close cooperation with the Estonian Research Council (ETAG), which administers grant instruments, and other government programmes related to digital transformation. Development of future priorities involves consultations among the Ministry of Education and Research, the Ministry of Economic Affairs, the R&D Council, the Academy of Sciences, universities, and businesses, supported by stakeholder engagement, analytical work, and foresight (Ministry of Education and Research of Estonia, 2021).

- In **Türkiye**, the process of defining research priorities is highly centralised (top-down), with key roles played by the President, the ministerial hierarchy, and the Scientific and Technological Research Council (TÜBİTAK). Methodologically, the process is based on analysing import dependency and pursuing full technological sovereignty, focusing on breakthrough technological missions (Kacır, 2025). Priorities are formalised through the nationwide vision National Technology Move and detailed in the 2030 Industry and Technology Strategy (Mohydin, 2024). Implementation occurs through vertical sectoral programmes (space, defence, digital technologies, etc.), with a strong emphasis on stimulating private sector participation.
- In **China**, scientific goals are integrated into major national plans such as Made in China 2025 and the long-term Science and Technology Development Plan (2021–2035). Implementation occurs through five-year plans and sectoral roadmaps coordinated by the Ministry of Science and Technology (MOST) in cooperation with the Chinese Academy of Sciences (CAS). Selection of priority research fields is a strategic political decision aimed at achieving technological self-reliance and leadership in emerging and critical technologies (quantum research, AI, semiconductors). The country combines fundamental research with applied solutions targeting key national priorities.

Taken together, examples of these countries show that approaches to setting research and innovation priorities differ not only in their organizational form (from top-down to bottom-up) but also in the underlying logic by which strategic priorities are translated into societal demand for research and innovation. In some systems, priority setting is driven by centralized strategic frameworks that articulate national missions and sovereign goals, while in others it emerges through structured stakeholder engagement, foresight, and co-creation mechanisms that link scientific programs to societal challenges. In all cases, effective priority setting combines a clear strategic vision with institutional mechanisms that preserve scientific autonomy, integrate business and academic perspectives, and allow for periodic review of priorities.

Implementation: Instruments for Transforming Ideas into Products

The implementation of research results is a critical link in the innovation cycle. It determines the capacity of national systems not only to generate knowledge but also to transform it into practical solutions—competitive products and socially valuable services. At this stage, the transition takes place from a scientific idea to its market realization, requiring an effective combination of institutional mechanisms, financial instruments, infrastructural support, and cross-sectoral collaboration. In contemporary conditions, the implementation of scientific priorities goes beyond the linear model of technology transfer and increasingly takes the form of an ecosystem process. Partnerships between the state, business, and the scientific community play a key role. The effectiveness of this process largely depends on the state's ability to act as an integrator, facilitator of innovation ecosystems, and catalyst of innovation demand (Mazzucato, 2018, Beaudry et al., 2021). Analysis of country practices reveals both the specificity of institutional solutions and the common patterns in building effective mechanisms for transforming knowledge into innovation. In this context, it is useful to examine national models for implementing scientific priorities and the instruments for commercializing and scaling research results within the economy:

- In **Germany**, the implementation of scientific priorities is based on a model of institutional partnership in which the state acts as a strategic coordinator and "anchor investor" in research infrastructure (Düngaupt et al., 2025). This model deliberately encompasses the full spectrum from fundamental curiosity-driven inquiry to applied industrial innovation, with distinct institutions assigned complementary roles within a coherent national research architecture. At the foundational end of this spectrum stands the Max Planck Society (Max-Planck-Gesellschaft), which operates on an explicitly different logic from applied research organisations: it provides long-term institutional funding to world-class researchers with near-complete autonomy over research agendas, deliberately shielding basic science from short-term economic or political pressures. The key institution responsible for the "idea-to-product" mechanism is the Fraunhofer Society, which operates on a co-funding principle: the state covers one-third of expenditures, incentivizing institutes to secure the remaining funds through industrial contracts and competitive grants (Czarnitzki & Licht, 2021). The state finances long-term thematic programmes and excellence clusters through the Wissenschaftsrat (n.d.) and DFG (Deutsche Forschungsgemeinschaft, n.d.), uniting universities and Mittelstand firms around strategic "missions" (e.g., Industry 4.0). The state diversifies financial risks with the private sector to preserve the country's global engineering leadership (OECD, 2025).

- In **the United Kingdom**, the state acts as a **public co-investor** that stimulates the transformation of scientific ideas into commercial products (Rossi & Athreye, 2021). The primary instrument for bringing research results to market is the network of applied Catapult centres, which provide businesses with access to costly infrastructure and expertise, supported by the UKRI holding. Through ARIA, the government invests in high-risk, high-reward breakthrough research and promotes knowledge transfer partnerships (KTPs), which embed university researchers directly into private-sector companies. A characteristic feature of the British model is the involvement of private capital in publicly funded scientific projects, creating new technology markets in strategic fields such as AI, quantum technologies, bioengineering, and new energy solutions.

- In **the Netherlands**, the implementation of scientific priorities relies on a triple-helix model (state–university–business) and a sector-based (top-sector) organisation of priorities. The state serves as a facilitator and co-investor in partnerships, forming strategic top-sector packages and stimulating public-private collaborations. Key regional hubs (e.g., Brainport Eindhoven, Wageningen) act as centres for implementation and technology demonstration. Implementation tools include joint sectoral roadmaps, financial support for Public-Private Partnerships (PPP) projects, innovation vouchers, tax incentives (WBSO), and dedicated scaling mechanisms for SMEs. Thus, the Dutch model provides systematic state coordination through investment risk-sharing, infrastructure platforms (testbeds, demonstration centres), while the private sector and regions define commercialization pathways (NWO, n.d.; Technopolis Group, 2025).

- In **Finland**, the model for implementing research results relies on collaboration and an ecosystem approach. The state acts as a partner through co-funding schemes and tax incentives. Business Finland (2026) formulates strategic directions (e.g., "Carbon-Neutral Industry"), while businesses and universities propose pathways to achieve these goals. The state additionally invests in research infrastructure (microelectronics centres, biotechnology pilot plants), providing access to private companies (Sotarauta, 2024).

- In **Sweden**, implementation takes place through long-term partnership platforms in which the state, via Vinnova (the Swedish government agency responsible for funding and coordinating innovation and research), invests in shared technological capabilities. Individual projects do not receive direct project-based funding (Grillitsch, 2024). The Swedish model focuses on strategic innovation hubs and mission-oriented ecosystems established under the national initiative Impact Innovation (Vinnova, 2024, 2025). This model combines direct subsidies with effective tax instruments.

- In **Italy**, implementation of scientific priorities is characterised by a structured multi-level system of state coordination. Strategic decisions are taken at the highest political level, while implementation is ensured through a broad network of ministries, research agencies, and specialised institutions. Operationally, the Ministry of Universities and Research (MUR) plays a central role by coordinating national scientific programmes, allocating basic funding to universities and research organisations, and setting competitive selection rules. At the same time, the Ministry of Economic Development (MISE) and the Ministry of Enterprises and Made in Italy (MIMIT) oversee applied research and industrial innovation, stimulating demand for R&D and supporting joint projects between industry and research institutions. Advisory and evaluation functions are performed by the National University Council (CUN) and the National Agency for the Evaluation of Universities and Research Institutes (ANVUR), which integrates performance-based principles into funding. Key institutional research providers include the National Research Council (CNR) and specialised public organisations such as INFN, ENEA, and the Italian Space Agency (ASI). Financial implementation relies on a combination of basic university funding (FFO), competitive calls (PRIN, formerly FIRB and SIR), and the National Research Fund established under the PNRR to support large programmes. The "Dipartimenti di Eccellenza" programme concentrates resources in leading research departments aligned with national priorities (Ministero dell'Università e della Ricerca, 2021).

- In **Estonia**, the implementation model combines the national digitalisation strategy with a flexible ecosystem for supporting start-ups and research infrastructure. The state serves as a coordinator and provider of digital platforms and foundational infrastructure (e-government, open data). Priorities are implemented through national RD&I strategies, competitive calls of the Estonian Research Council (ETAg), and programmes of Enterprise Estonia (EAS). Main instruments include targeted project grants, university–business co-funding schemes, national research infrastructures, and urban/regional science parks (Tehnopol, Tartu Science Park). Estonia emphasises digital solutions, rapid scaling of pilot projects into national e-services, and active use of EU funds to expand initiatives (Ministry of Education and Research of Estonia, 2021).

- In **Türkiye**, implementation is marked by strong state intervention. The government effectively creates the demand for scientific research (Kacır, 2025). A key example is the HAMLE (Technology-Oriented Industry Move) initiative, which offers a full financing package—from R&D support and tax incentives to capital investments in manufacturing and preferential access to public procurement (Republic of Türkiye, 2025). The country has built one of the region's most successful technopark networks, enabling academia–industry collaboration, incubation, and acceleration of start-ups, including clusters in the defence sector (TGBD, n.d.). Large industrial firms such as Aselsan and TUSAŞ also play a central role by investing heavily in R&D and creating stable demand for innovation.

- In **China**, the implementation of scientific priorities is characterised by strong vertical integration, with the state acting as the chief strategist and principal customer that mobilises resources across society. The main instruments for translating plans into research activity are the State Key Laboratories and specialised science and technology parks created to advance priority fields. The state is a shareholder in thousands of start-ups whose activities support national security and technological sovereignty (Groenewegen-Lau & Laha, 2023, Yi & Tang, 2025).

Across the countries examined in the study, the state assumes different roles—ranging from a facilitator and co-investor of innovation ecosystems to an active driver of demand and strategic purchaser of innovation, which shapes differences in commercialization mechanisms. Models based on partnership-oriented and decentralized investment structures support gradual and sustainable integration of science and business, whereas more directive and mission-oriented approaches enable the concentration of resources and the accelerated scaling of technologies in priority areas. Accordingly, cross-country differences should be interpreted not as variations in "success," but as distinct types of state involvement and investment logics for implementing scientific priorities.

Impact Indicators: Economic and Scientific Outcomes of R&D Policy

The effectiveness of R&D policy is reflected in a nation's capacity not only to generate knowledge but also to convert it into tangible economic, technological, and scientific outcomes. However, achieving these results depends on sectoral policies and a robust institutional framework, including protection of property rights. The most widely used impact indicators include changes in countries' positions in international rankings of innovation competitiveness, the dynamics of scientific publication output, patenting activity, and the degree of commercialization of research results.

One of the most well-known international benchmarks is the Global Innovation Index (GII) (the dynamics of the analysed countries' rankings are presented in Annex A, Table A.1), which reflects the ability of countries to create innovations and convert scientific results into economic and technological development.

Analysis of the dynamics of countries' positions in the Global Innovation Index reveals divergent trajectories in the evolution of their national innovation systems. Sweden, the Netherlands, the United Kingdom, and Finland represent a group of stable leaders that, throughout 2007–2025, have achieved and maintained high positions (top-10) in the GII owing to well-developed institutions, stable investments in science and technology, and effective innovation ecosystems. China and Estonia demonstrate accelerated advancement: both countries have significantly improved their rankings (China from 29th place in 2007 to the top-10 in 2025; Estonia from 31st to 16th), indicating the effectiveness of intensive reforms in R&D, digitalisation, and innovation infrastructure. Germany, by contrast, has lost ground—from 2nd place in 2007 to 11th in 2025—potentially reflecting a slowdown in structural modernisation and global pressure from emerging innovation centres. Meanwhile, Italy and Türkiye fall into the category of limited-dynamics countries: despite moderate baseline positions in 2007 (Italy ranked 24th and Türkiye 45th), their progression has remained modest (Italy 28th, Türkiye 43rd in 2025), indicating institutional inertia and slower modernisation of innovation policies (Dutta & Caulkin, 2007; WIPO, 2025a).

Scientific outcomes of R&D policy are also reflected in publication output, which indicates the productivity of the research sector and the country's ability to generate new knowledge. The dynamics of the number of publications in the Scopus database for 1950–2025 across the analysed countries are presented in Annex B (Figure B.1), and their disciplinary structure in Table B.1. An overview by publication output by disciplinary domain by country shows the following picture:

- In **Germany**, the dominant scientific fields in 2025 remained engineering (9.9%), physics and astronomy (9.5%), biomedical sciences (7.2%), and medicine (15.5%), which reflects the persistence of a classical science-and-technology model. At the same time, the country shows substantial growth in digital domains: computer science tripled its share (from 2.4% to 7.2%) and has become one of the main drivers of expansion.

- In 2025, the scientific profile of **the United Kingdom** remained diversified, but with a noticeable shift from traditional fundamental fields toward applied and interdisciplinary domains: although medicine (17.8%) and biomedical sciences (6.3%) retain a leading role, their combined share has declined compared with 1950–2000, while computer science has significantly strengthened its position (5.8% compared with 2.3% earlier), and the social sciences (9.7%) have become one of the most dynamic areas.

- In 2025, **the Netherlands** retained a biomedical core with high shares of medicine (21.0%) and biochemical sciences (7.2%), complemented by stable positions in engineering (7.5%) and noticeable growth in computer science (6.0%). Compared with 1950–2000, the country is gradually diversifying, with digital and environmental sciences strengthening the traditional medical-academic profile.

- **Finland** in 2025 demonstrated a transition from medical research dominance (from 29.3% to 13.2%) to a model oriented toward digital, engineering, and social fields: computer science grew to 8.77%, engineering increased to 9.95%, and the social sciences expanded to 7.66%.

- In 2025, **Sweden** maintained strong positions in medicine (17.9%) and biomedical research (7.7%), although their shares have significantly decreased compared with 1950–2000. This has been accompanied by notable growth in computer science (6.0%), engineering (8.8%), and environmental disciplines (5.5%). The structure of scientific publications is becoming increasingly balanced: the traditionally strong biomedical sector is gradually integrating with technological and socio-technical domains.

- **Italy** maintains the dominance of medicine (18. 5%), although its share has declined; meanwhile, digital disciplines—particularly computer science (7.2%)—have strengthened their positions, and engineering (9.8%) along with the natural sciences remains stable. Structural changes are gradual and incremental, creating an inertial but balanced system.

- **Estonia** demonstrates one of the most transformed profiles: the shares of medical and natural sciences have declined, while computer science sharply increased from 2.30% to 7.7%, and social sciences in ʹa broad sense (ASJC classification) — from 2.7% to 10.3%—becoming leading fields. The share of medicine decreased to 7.9%, and biomedical sciences to 6.0%.

- In **Türkiye**, medicine still dominated in 2025 (22.1%), though its share has decreased compared with the previous period, while computer science (from 3.0% to 5.9%) and social sciences (from 1.4% to 5.4%) show stable growth. The country's scientific profile is becoming more diversified, although the pace of change remains slower than in rapidly transforming innovation systems.

- **China** demonstrates the most techno-centric profile among all analysed countries: in 2025, engineering (17.5%), physics (8.5%), materials science (9.1%), and computer science (9.5%) formed the core of a system oriented toward applied and industrial research. Compared with 1950–2000, the country has significantly increased the share of digital technologies while maintaining a strong foundation in natural and technical sciences. Medicine (8.2%) and the humanities remain peripheral, underscoring China's strategic focus on technological breakthrough and scaling engineering-driven innovation.

Measuring the return on scientific research requires patent analysis, which makes it possible to track the life cycle of innovations—from idea generation and research validation to commercialization and market entry. While such an analysis mostly goes beyond the scope of this document, here we show a brief overview of the state of the art. Annex C, Table C.1 presents a comparative analysis of patent application-to-grant conversion rates for selected countries for 1990–2024, while Table C.2 shows the distribution of published patent applications by technology fields in 1995 and 2022. These data allow the following trends to be observed:

- **Germany's** patent system is characterised by stability: application-to-grant conversion fluctuates but demonstrates long-term growth from 23.7% in 2000 to 40.4% in 2024. The technological profile remains entrenched: in 2022, Mechanical Engineering (43.6%), Electrical Engineering (26.6%), and ICT (11.4%) dominate, while chemistry and materials declined to 5.5%.

- **The United Kingdom** demonstrates high and rising conversion rates: from 24–36% in 1995–2015 to over 50% in 2021–2022, indicating increasing quality of innovation outputs. Sectorally, ICT (25.3%) strengthened its position, alongside consistently high shares in Electrical Engineering (17.5%) and Mechanical Engineering (22.7%) in 2022. Compared with 1995, high-tech sectors expanded noticeably, highlighting a shift toward digital and engineering fields.

- **The Netherlands** exhibits consistently high conversion levels (86.3% in 2024), along with rising output intensity in preceding years. In 2022, the profile is dominated by Mechanical Engineering (34.1%), Electrical Engineering (14.7%), ICT (10.0%), and Medical & Biology (11.1%), forming a balanced and mature innovation system.

- **Finland's** conversion rates show uneven dynamics: high values early in the period (61.9% in 1995; 85.3% in 2005) are followed by declines after 2010 to around 32–46% in the 2020s. This may indicate growing volumes of applications not always resulting in granted patents. Sectorally, Finland in 2022 strengthens ICT (17.90%), Mechanical Engineering (26.86%), Electrical Engineering (15.08%), while the share of chemistry and materials decreases (from 21.72% in 1995 to 15.31% in 2022).

- In **Sweden**, patent conversion remains moderate with noticeable fluctuations (31.7% to 69.9%) but stabilises around 35–40% in 2022–2024. Sectorally, in 2022 Mechanical Engineering (37.3%), Electrical Engineering (15.8%), ICT (11.7%), and Chemistry & Materials (11.2%) dominate.

- **Italy** demonstrates significant instability in conversion: from extremely high values due to accumulated applications (106.9% in 1995; 165.6% in 2010) to 74.5% in 2024. These high values may reflect accounting specifics or low annual application volumes. Sectorally, Italy in 2022 showed strong positions in Mechanical Engineering (40.4%), Electrical Engineering (10.5%), ICT (8.5%), and Consumer Goods (14.2%), highlighting a blend of industrial and applied sectors.

- **Estonia** exhibits extreme variability in conversion rates (0% to 428.9% in 2005), explained by small patent volumes and sharp fluctuations in applications. Sectorally, in 2022 the country showed increase in Electrical Engineering (18.2%) and Mechanical Engineering (31.8%), declines in chemistry and materials (22.7% vs. 34.7% in 1995), and modest shares in medicine and ICT, reflecting a shift toward technical and digital fields.

- In **Türkiye**, conversion has gradually decreased (45.1% to 32.8% in 2024), indicating uneven innovation performance and difficulties in bringing applications to granted patents. Sectorally, in 2022 the system was characterised by strong positions in Mechanical Engineering (30.34%), ICT (14.99%), and stable shares in Electrical Engineering (12.01%), reflecting an industrially oriented economy.

- **China** shows consistently rising conversion rates—from 18.1% in 1995 to 57.2% in 2024—indicating increasing patent system efficiency and higher application quality. The sectoral profile confirms the technological nature of the economy: in 2022, ICT (26.9%), Electrical Engineering (20.6%), and Mechanical Engineering (20.9%) dominate, while chemistry and materials have halved (13.4% vs. 25.7% in 1995). China consistently strengthens its position in high-technology sectors.

The country review shows that stable innovation leaders exhibit balanced publication patterns, stable patenting performance, and a gradual shift to digital and applied industries, while fast-growing systems exhibit a pronounced re-specialization towards ICT- and engineering-oriented research. In contrast, countries with limited innovation dynamics are characterized by slower structural changes, weaker patent conversion, and difficulties in transforming scientific potential into high-value technological outputs. These patterns suggest that long-term institutional coherence and alignment of research profiles with commercialization pathways are critical determinants of R&D policy effectiveness.

Impact of Crises: Responses, Adaptation Mechanisms, and Opportunities

The contemporary stage of development of science and technology systems unfolds amidst continuous crisis-induced disruptions. The COVID-19 pandemic, wars, energy shocks, disruptions to global supply chains, and intensifying technological competition have highlighted the importance of effective research policy and its adaptability and resilience to external shocks (Paunov & Planes-Satorra, 2021). At the same time, crises also are of interest to scientists as they raise new questions about our systems and societies, and hence, bring opportunities for inquiry and innovation. In this context, the ability of national science systems to respond rapidly to crisis dynamics, reorient priorities, and mobilize resources determines their role in ensuring economic stability and national security.

The crises of recent years have demonstrated that science increasingly functions as an operational response tool (Gross & Sampat, 2022a). This has been accompanied by revisions to funding mechanisms, accelerated decision-making procedures, the development of interdisciplinary research, and the integration of science into security, public health, and energy policies.

Against this background, an analysis of how different countries responded to crisis challenges helps identify effective mechanisms for adapting science systems, instruments for rapid resource mobilisation, and approaches to the transformation of research priorities. This, in turn, enables conclusions about the role of science as an element of anti-crisis policy and long-term state resilience.

The COVID-19 pandemic became a powerful impulse for accelerated digital and security transformation in most of the analysed countries (Paunov & Planes-Satorra, 2021). Whereas biosafety had previously been viewed primarily in the context of agricultural sciences and veterinary research, the pandemic shifted the focus toward the broader paradigm of Life Sciences:

- **Germany** prioritised overcoming bureaucratic barriers through the OZG Act, which required all public services to be digitised, as well as intensive patenting of solutions for "digital twins" in industry (EPO, 2023). In the field of biosafety, new legislation on the use of medical data was adopted (Federal Ministry of Health, 2023) to support predictive public health monitoring.

- **The United Kingdom** strengthened its position as the world's third-largest tech market by focusing on exporting solutions in FinTech and AI (UK Tech Nation, 2023), while integrating these innovations into healthcare through the Life Sciences Vision strategy (Department for Business, Energy et al., 2021).

- **The Netherlands** significantly increased funding for healthcare and biomedical research (CEPI, 2023). With government support, the CEPI coalition—an international partnership for epidemic preparedness—was established and financed. In 2020, the Netherlands allocated €50 million to CEPI and an additional €14 million in 2023, prioritising pandemic-related research.

- For the Nordic countries (**Finland, Sweden**), the pandemic became a catalyst for deep digital transformation. According to the Digital Economy and Society Index (DESI), Finland ranked first and Sweden fourth in 2021–2022 (European Commission, 2022). During this period, both countries demonstrated record growth in patent applications in digital communication (EPO, 2023) and advanced the model of a "digital state as a service." Sweden updated its National Life Sciences Strategy (2021), shifting the focus from economic goals to security-oriented ones and designating biotechnological innovation and digital medical data as critical infrastructure (Government Offices of Sweden, 2021). Finland integrated life sciences into its "comprehensive security" framework, reorienting R&D priorities toward biotechnology and digital medicine as key components of national technological sovereignty (VTT, 2021).

- **Italy** revised its science funding system after the pandemic, using EU recovery funds to support R&D and innovation. In 2021, it adopted Next Generation Italia, part of the EU's NextGenerationEU package. Of this, €11.7 billion was allocated to science, research, and innovation, including support for young researchers, research infrastructures, and R&D projects (Paterlini, 2021). The PNRR recovery plan included major investments in digital transformation and technological innovation, which reshaped post-COVID research priorities.

- **Estonia** rapidly redirected resources in the pandemic period toward health research, epidemiology, vaccine development, and mental health studies. Attention also increased toward digital solutions (telemedicine, remote education) and the socioeconomic impacts of the pandemic. Estonia implemented emergency COVID-19 research calls through the Estonian Research Council (2020).

- **Türkiye** focused its pandemic-era R&D on scaling national digital platforms in logistics and e-commerce (Digital Transformation Office of Türkiye, 2023), and on deploying the national digital healthcare platform e-Nabız (European Institute of Public Administration, n.d.).

- **China** used this period to consolidate its leadership in contactless payments, warehouse robotics (IFR, 2023), and smart hospitals.

Wars, trade disruptions, the pandemic, and the energy crisis influenced shifts in research priorities in the analysed countries, directing attention toward technological sovereignty, digitalisation, and energy autonomy.

- **Germany** reoriented its scientific priorities from optimising fossil fuel use to fundamental research on renewable energy, particularly hydrogen technologies (Green Hydrogen) under the updated Hydrogen Strategy (2023). Another major priority was industrial digitalisation—especially in Smart Grids (ERA, 2023; German Federal, 2023).
- **The United Kingdom** responded with the British Energy Security Strategy (2022), prioritising research on small modular nuclear reactors and quantum technologies (UK Government, 2022; National, 2023; Price, 2021).

- **The Netherlands** created new national research consortia (HyUSE, HySUCCESS) within the GroenvermogenNL programme dedicated to green energy research (MNEXT, 2024). The National Energy and Climate Plan 2021–2030 outlines funding and research priorities in low-carbon technologies (renewables, energy efficiency, hydrogen, energy storage), formalising the government's science priorities in response to energy challenges.

- For the Nordic countries (**Finland and Sweden**), the military threat catalysed a shift toward a "technological fortress" model, aligning civilian innovation with defence needs (NATO DIANA, 2025).

- **Italy**, following the 2008 crisis, shifted research priorities toward strengthening researcher capacity and infrastructures rather than focusing on narrow specialised projects (Bollettino ADAPT, 2016).

After the 2012 debt crisis, the focus turned to R&D spending efficiency and transparency. The National Research Programme 2015–2020 introduced the "Efficiency and Quality of Expenditure" initiative, promoting stakeholder involvement and coordination of national and regional R&D initiatives. In 2025, five new calls—totalling €200 million—were launched to support innovation in renewable energy under Mission Innovation 2.0 (Review-Energy, 2025).

- **Estonia** strengthened energy security, climate neutrality, and renewables as a distinct priority within the RDIE Strategy 2021–2035. The Estonian Research Council supports research on renewable energy, energy efficiency, decarbonisation, and climate policy through targeted calls (OECD, 2023). Research informs NECP 2030 scenarios for 100% renewable electricity and phasing out oil-shale energy (Government of Estonia, 2023). Estonia also supported the establishment of Hydrogen Valley Estonia, integrating universities and research institutes in hydrogen production, storage, and use as a component of energy security (Science Business, 2024). Research policy further fosters the integration of energy research with digital technologies (smart grids, digital energy management).

- **Türkiye** responded to various crises by prioritising full localisation across critical sectors—defence, semiconductors, biotechnology, and energy—shaping its science priorities (Republic of Türkiye Ministry of Industry and Technology, 2019).

- **China**, amid crises, redirected scientific capacity toward full import substitution in critical sectors (microelectronics, seed production, software). The country also prioritised carbon-storage research to reconcile coal-based energy with global environmental standards, and accelerated robotics and AI development. The government highlighted its commitment to "new quality productive forces," emphasising leadership in AI, biomedicine, robotics, and quantum technologies, as well as breakthroughs in independent chip R&D (Li, 2026; Chen & Baptista, 2026; State Council Information Office, 2026).

Overall, the analysis of crisis responses shows that crises function not only as sources of destabilization but also as catalysts for the structural reconfiguration of national science systems, reshaping both policy priorities and instruments. Across most of the examined countries, crisis conditions have reinforced the role of science in areas such as digitalization, biomedicine, energy autonomy, and technological security. For Ukraine, the key lesson is that under conditions of systemic shocks, investment in R&D is treated not as a supplementary measure but as a core mechanism for overcoming economic stagnation and strengthening national security, as evidenced by the experiences of Finland, Sweden, and Italy. At the same time, the case of Türkiye illustrates how crisis dynamics can trigger a strategic reorientation toward localization and the construction of end-to-end technological value chains in critical sectors, with an emphasis on increasing value added and long-term competitiveness.

Conclusions for section 1

The comparative analysis of international approaches to identifying priority directions in research and innovation has revealed both universal patterns and significant differences shaped by diverse historical, institutional, and economic contexts. Despite the considerable variability of models, all examined countries demonstrate a shared logic in the evolution of research priority-setting, which progresses through successive stages linked to national security, post-crisis reconstruction, the formation of innovation-driven competitiveness, and the strengthening of long-term societal resilience. This four-stage trajectory from “war mode” to addressing complex societal challenges, is typical for states that have experienced warfare, systemic disruptions, and large-scale modernization cycles.

At the initial stage, priorities are determined by the needs of defence, cybersecurity, and the protection of critical infrastructure, as evidenced by the cases of Israel, Croatia, China, and Türkiye. The dominance of defence and technological objectives is accompanied by centralized decision-making, accelerated funding mechanisms, and close integration of science with the security sector. For Ukraine, this experience is particularly relevant, demonstrating the need to strengthen defence-related R&D and digital resilience as the foundation of a significant share or research priorities during wartime.

Both during war and following the end of warfare, science becomes a key instrument for rebuilding infrastructure, modernizing industry, restoring research institutions, and addressing environmental damage. Mission-oriented approaches, characteristic of Germany, the United Kingdom, the Netherlands, Italy, and post-war Croatia, confirm that effective alignment of government reconstruction goals with scientific tools is essential for national recovery. These countries show that the restoration of science forms a fundamental pillar of broader economic revitalization. For Ukraine, this underscores the need to integrate research into all major components of post-war recovery—from demining to green energy and industrial transformation, and many activities cannot be postponed and should be launched immediately.

The subsequent development trajectories of the analysed countries demonstrate that once reconstruction tasks are completed, research priorities shift toward enhancing technological competitiveness and advancing high-value-added sectors. The experiences of Finland, Sweden, and South Korea confirm that at this stage it is vital to ensure coordination between research policy, industrial strategy, and human capital development. High levels of institutional autonomy for research organisations, coupled with strong support for applied research and innovation, allow these states to integrate into global value chains and sustain long-term growth.

At the final stage, research policy transforms into a systemic response to long-term societal challenges such as demographic change, public health, environmental sustainability, and digital transformation. The experiences of Estonia, the Nordic countries, and EU mission-oriented frameworks show that science becomes a driver of societal resilience and quality of life. These systems prioritize the integration of technological, social, and environmental innovations, enabling societies to adapt to complex global dynamics.

The analysis of modern priority-setting models demonstrates that contemporary research systems increasingly combine strategic state leadership with broad stakeholder involvement either in a hybrid or decentralized model, with the exception of China and Türkiye which maintain strong political centralization. Germany, Finland, Italy, and similar countries illustrate hybrid approaches in which the government sets overarching frameworks, while research organisations and businesses contribute substantive inputs. Sweden, the Netherlands, and Estonia employ decentralized and inclusive models based on expert evaluation, cross-sectoral consultations, and open public engagement (such as the Dutch National Science Agenda). Equally important are the differences in implementation instruments. In countries with advanced research systems (Germany, the UK, the Netherlands), implementation relies on partnership models in which the state acts as an "anchor investor" and industry provides scaling capacity. The Nordic countries operate through ecosystem platforms and mission-driven innovation partnerships. Estonia demonstrates a model of rapid deployment of digital solutions through agile state platforms. In contrast, China and Türkiye implement vertically integrated technological programmes supported by state-owned enterprises. All these models confirm that effective implementation requires not only financial resources but also institutional coherence and strategic continuity.

The effectiveness of research policy is further reflected in transformations of scientific profiles, publication dynamics, research structures, and patenting efficiency. A general trend across all studied countries is the strengthening of digital and engineering disciplines, although the speed of structural change varies substantially. China and Estonia demonstrate rapid technological restructuring, whereas Italy and Türkiye follow more incremental trajectories. Patent analysis confirms the dominance of engineering, electronics, and ICT, while consistently high conversion rates in the Netherlands, Germany, and China indicate mature and efficient innovation ecosystems.

The experience of crisis periods shows that pandemics, energy shocks, and war significantly reshape research policy, shifting emphasis toward digitalisation, biosafety, energy autonomy, and technological sovereignty. In most countries, investment in R&D during crises is viewed not as expendable but as a key mechanism of stabilisation and modernisation. Adjustments to research priorities in Germany, the UK, Nordic countries, the Netherlands, Italy, Türkiye, and China demonstrate that science becomes an integral part of crisis management and national security strategies.
In summary, the international experience of forming and implementing research priorities demonstrates the complex, multi-level, and dynamic nature of modern research systems. Despite differences between countries, several factors remain fundamental: strategic continuity, institutional coordination, mission-oriented frameworks, a balanced combination of fundamental and applied research, and the capacity of research systems to adapt to crisis conditions.

Specific lessons from research priorities setting of analysed countries are:

- Framework, way of research priorities setting is the questions of "how" and what is the starting point for setting the research priorities imply operational mechanisms;
- There are two ways of setting the research priorities for every country: 1) dealing with limited resources (energy, water, oil, minerals) for compensation of limitations; 2) dealing with increasing productivity in different industries;
- Difference between research priorities setting in stable and emergency contexts depends on lag of achieving research results. Emergency leads to prioritizing short-term results.
- These findings provide a valuable basis for developing recommendations to strengthen Ukraine's research policy during wartime and throughout post-war reconstruction.

SECTION 2. EVALUATION MATRIX AND PRIORITY MAPPING DESIGN

Glossary	
Terminology	Definition
Pillar (National Grand Challenge)	The highest strategic level. Represents the broad socio-economic domains (e.g., Recovery, Security) that define the national recovery agenda.
Mission	A targeted, time-bound challenge within a Pillar. It serves as the bridge between high-level policy and specific R&D activities.
Descriptor / R&D Direction	The specific thematic field or technological area subject to evaluation (e.g., “Hydrogen storage” within the Energy Security mission).
Indicator	A standardized metric (e.g., Strategic Relevance, R&D Capacity) used to quantitatively assess each R&D direction on a 4-point scale.
Qualifier	The specific value (Indicator + Level) assigned to an R&D direction, determining its final score and position on the Priority Graph.
Driver	An external or internal trend (e.g., AI proliferation, Brain Drain) used for stress-testing the resilience of chosen priorities.

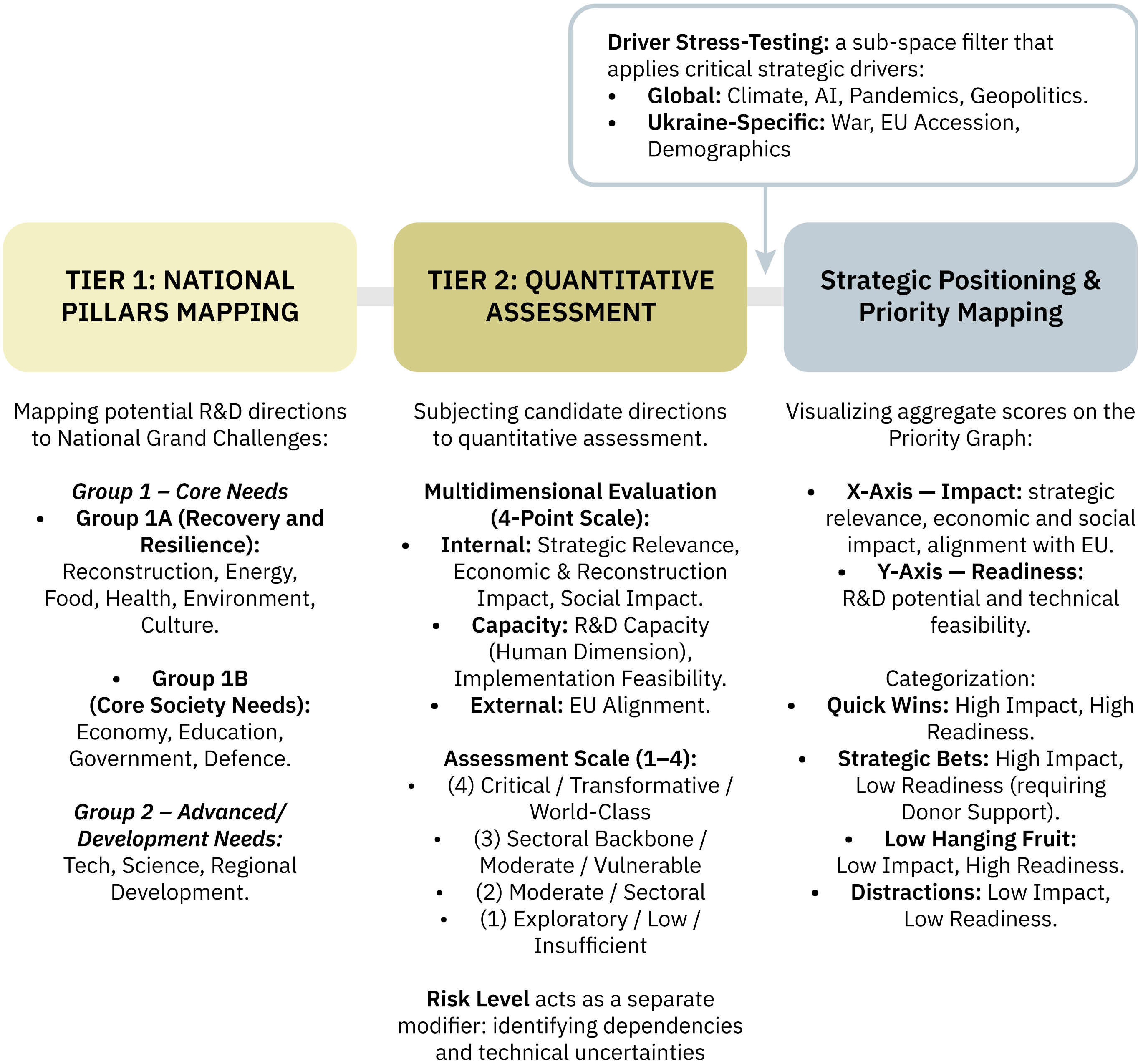
The synthesis of international experience presented in the previous section demonstrates that a country’s successful research policy is a dynamic process where priorities are determined by the developmental phase of the crisis experienced by a society, the nature of external challenges, and the system’s institutional readiness to implement chosen strategies. In this context, it is not only the selection of priorities that matters, but the selection mechanism itself, as it ensures process continuity and the efficient use of limited resources, particularly during crises.

As Ukraine currently faces a prolonged crisis caused by Russia’s military aggression, there is an urgent need for an objective toolkit capable of balancing immediate defence needs with long-term requirements for innovative competitiveness and integration into the European Research Area. To address this, the decision-making process must move beyond qualitative assessment toward a structured methodology.

Prioritizing research and development (R&D) directions involves balancing academic excellence with practical utility. Funding organizations and governments often use multi-criteria frameworks aimed at evaluating potential directions through a specific system of descriptors/indicators. Notable examples are the “Heilmeier Catechism” used by the U.S. Defense Advanced Research Projects Agency (DARPA) to prioritize the funding of research proposals [https://www.darpa.mil/work-with-us/heilmeier-catechism], or multi-criteria analysis used by the Australian

Commonwealth Scientific and Industrial Research Organisation (CSIRO) to weigh attractiveness versus feasibility and articulated further in the UK Technology Foresight Programme to introduce the dimensions of cost and timescale (Georghiou & Cassingena-Harper, 2011). The same type of approach has been used in the latest 2024 Ukrainian foresight study (Popovych, 2024). At the same time, in the EU foresight context, a concept of ‘‘grand societal challenges’’ has been coined, with the rationale of moving beyond rigid thematic approaches. The focus of the European research on the grand challenge has been acknowledged since the 2010 report on the European Technology Platforms by DG Research (European Commission, 2010). To ensure, on the one hand, the possibility to rank priorities based on a quantitative analysis framework, and on the other hand to maintain compatibility with the EU strategies, we propose to use a **two-tiered mapping framework**. Each research/technology direction or field to be analyzed in the course of the foresight study should be placed on a “map” in the Descriptor space (figure 2.1).

Figure 2.1. Integrated Foresight Assessment Framework



In the **first tier**, potential R&D directions are mapped to National Grand Challenges (Pillars) to establish their baseline relevance for fundamental societal needs.

1st level descriptors: "national grand challenges" / "pillars"

Group 1 – Core Needs

Group 1A – Recovery and Resilience

- Post-War Reconstruction (infrastructure, demining, housing, reintegration of de-occupied areas)
- Energy Security and Independence (separate from general economy due to criticality)
- Food Security and Agriculture (Ukraine's strategic sector)
- Health and Care (including trauma care, rehabilitation, mental health)
- Environment and Climate Adaptation (including biodiversity conservation, habitat restoration, ecosystem services)
- Culture and National Identity (including heritage and national memory)

Group 1B – Core Society Needs

- Sustainable Economy (manufacturing, services, SME development)
- Education and Skills Development
- Effective Government and Justice
- Defence and Security

Group 2 – Advanced/Development Needs

- Advanced Technology (capable of driving the economy)
- Excellent basic science (enabling access to advanced technology)
- Regional development (including smart specializations and territorial capital)

In the **second tier**, each candidate direction is subjected to a quantitative assessment using specific ***Qualifiers*** defined along multiple dimensions **(*Indicators*)**. A qualifier is defined as a pair (***Indicator + Qualifier Level). Qualifier Levels*** utilize a 4-point assessment scale to evaluate the R&D direction across the following dimensions:

Internal dimension

- **Strategic Relevance:** Assessing criticality for national defence, critical sectors and dual-use potential.
- **Economic & Reconstruction Impact:** Evaluating potential for GDP growth, export, and post-war recovery.
- **Social Impact:** Estimating potential to address societal needs, improve quality of life, promote equity and inclusion, and strengthen social cohesion.

Capacity

- **R&D Capacity (Human Dimension):** Assessing the readiness of existing human capital and research teams.
- **Implementation Feasibility:** Estimating infrastructure requirements and capacity for funding.

External dimension

- **EU Alignment:** Measuring compatibility with Horizon Europe clusters and the European Research Area.

In addition to descriptors, one should identify ***Drivers:*** external and internal factors/trends that are deemed crucial for forming the technological/political/environmental background of the foreseeable future (table 2.1), e.g., global climate change, rise of multiresistant infections, clean water shortage, proliferation of AI-based tech, political instabilities, etc.

Table 2.1. Strategic drivers of R&D development

Scope	Key Strategic Drivers Examples
Global	Climate & Environment; AI & Automation; Cybersecurity; Geopolitical Instability; Pandemics/AMR; Resource Scarcity; Energy Transition.
Ukraine-Specific	Post-war Reconstruction; Military Threats; EU Accession; Demographic Challenges; Energy Vulnerability; AgroTech Modernization; Digital Government.

These drivers should serve as a 'stress-test' filter to determine whether a specific R&D direction is resilient to Driver X. Although drivers can conceptually be viewed as additional indicators, they are better maintained within a separate subspace.

To visualize the aggregate scores derived from indicator analysis, it is proposed to use the **Priority Graph**—a strategic tool that maps each R&D direction within a unified "Impact vs. Readiness" coordinate space, its layout is illustrated in the figure below (figure 2.2).

The methodology categorizes directions along two primary vectors:

- **X-Axis — Impact:** Represents the strategic significance of the direction, integrating strategic relevance, economic and social impact, and alignment with European Union standards and strategies.
- **Y-Axis — Readiness:** Assesses the actual capacity to implement the direction, based on existing R&D potential (human capital, research expertise) and technical feasibility.

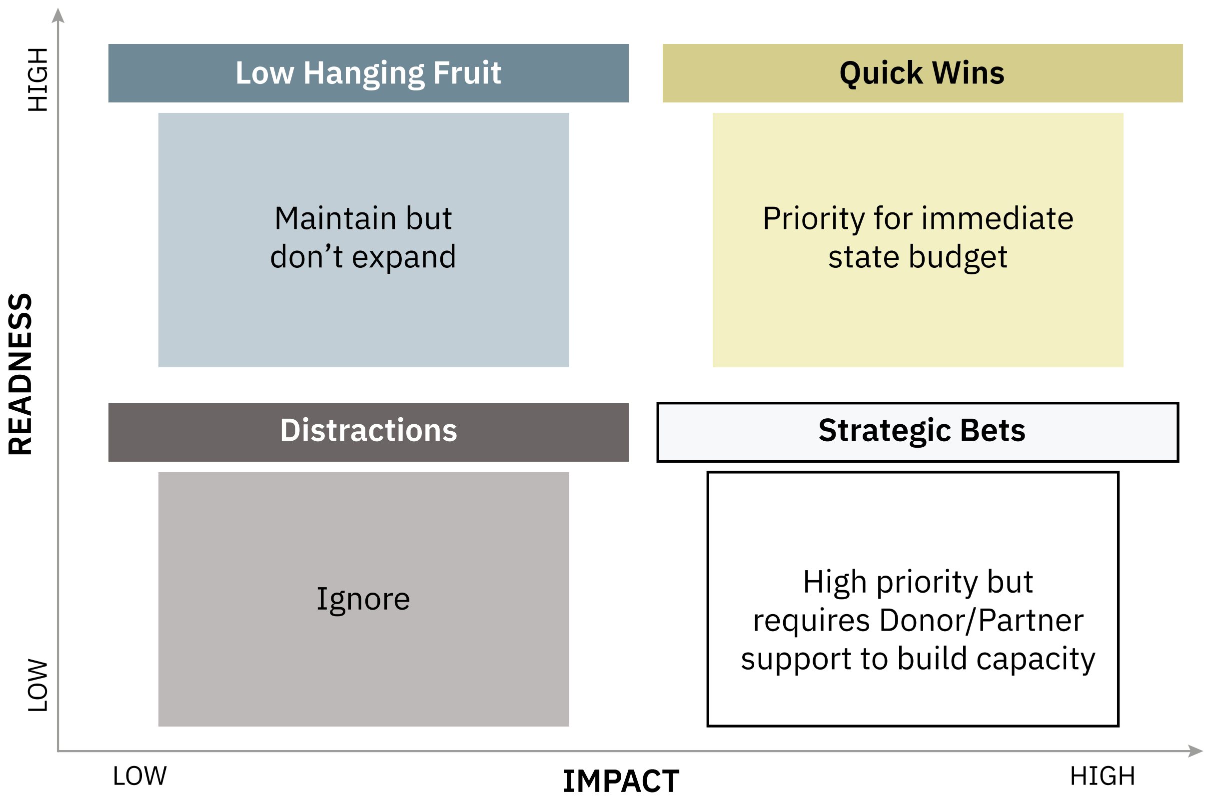


Figure 2.2. Priority Mapping Graph: Impact vs Readiness Framework

The resulting quadrants of the Priority Graph can be divided into:

- "Quick Wins" (High Readiness, High Impact): Priority for immediate state budget.
- "Strategic Bets" (Low Readiness, High Impact): High priority but requires *Donor/ Partner support* to build capacity.
- "Low Hanging Fruit" (High Readiness, Low Impact): Maintain but don't expand.
- "Distractions" (Low Readiness, Low Impact): Ignore.

One should remark that the actual ranking based on the results of the mapping according to the proposed framework could be performed with the help of more sophisticated techniques such as Analytical Hierarchy Process (AHP) (Saaty, 1990) or TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Hwang & Yoon, 1981).

2nd level descriptors: "qualifiers"

The attribution of a R&D direction/field to a ***qualifier*** is based on respective ***assessment criteria.***

The table below provides examples of possible indicators, qualifier levels, and assessment criteria***:***

Table 2.2. 2nd level descriptors: qualifiers and their signatures

INDICATOR	QUALIFIER LEVELS	ASSESSMENT CRITERIA
STRATEGIC RELEVANCE	**(4) Critical / Existential** for pillar(s) X, Y	Essential for national defense/security (directly or dual-use), or for survival of critical infrastructure. (OR) Required for the pillar to function, failure to develop this creates a severe vulnerability.
	(3) Systemic Enabler	(Horizontal priority). Foundational technology that unlocks capabilities and improves competitiveness across 3+ pillars.
	(2) Sectoral backbone	(Vertical priority). Critically important to ensure survival or long-term resilience for specific core sector(s) (e.g., sustainability, climate goals compliance, important in the context of response to a specific driver) of 1 or 2 pillars (e.g., metallurgy and grain export).

INDICATOR	QUALIFIER LEVELS	ASSESSMENT CRITERIA
	(1) Exploratory/background	Maintains research capacity in emerging areas but no clear link to national pillars, not critical for short-term or mid-term survival or recovery. Potential future value not recognizable or at over-the-horizon time scale.
ECONOMIC & RECONSTRUCTION IMPACT	**(4) Transformative**	Significant export potential; (OR) Massive yearly revenue > 1% GDP; (OR) Essential for urgent recovery goals (e.g., cheap housing, demining, energy, etc.); (OR) Aligns with smart specialization of region(s).
	(3) High	Solves a major/acute domestic or regional economic bottleneck; (OR) Creates significant high-value employment in recovery zones.
	(2) Moderate	Viable commercial potential in a non-critical sector, taking up a visible share of the domestic market; (OR) Reduces dependence on foreign tech/products in non-critical sectors, but no export value.
	(1) Low / unclear	Commercialization path not recognizable or at over-the-horizon time scale; (OR) commercial potential present, but the market share is negligible.
SOCIAL IMPACT	**(4) Transformative**	Fundamentally improves quality of life for large population segments (5%+ of population) or critical vulnerable groups; (OR) Addresses critical social challenges (e.g., post-war trauma, displacement, accessibility); (OR) Builds national resilience (strengthens national identity, community bonds, or social trust).
	(3) High	Significantly improves conditions for specific population groups; (OR) Addresses important social needs or inequalities (e.g., education access, healthcare gaps, regional disparities); (OR) reduces inequalities (e.g., urban-rural, income, disability, gender, age);
	(2) Moderate	Improves conditions for smaller groups or provides incremental improvements; contributes to recognized but non-critical social goals.

INDICATOR	QUALIFIER LEVELS	ASSESSMENT CRITERIA
	(1) Low/unclear	Primarily technical focus, social benefits only indirect, or not recognizable, or at over-the-horizon time scale.
R&D CAPACITY	**(4) World-Class**	Strong research teams recognized globally/EU, currently active and operational within Ukraine. Resources and personnel are available (own or effective network).
	(3) Regional	Strong competence recognized in Eastern Europe/domestically. Teams are intact and capable of leading consortiums.
	(2) Isolated/Vulnerable	Capabilities existed but have been degraded (damaged labs, brain drain); (OR) Emerging capabilities. High potential but fragmented. Small teams or individual stars with high potential but requiring investment/consolidation/ talent repatriation to enable scaling of the impact.
	(1) Insufficient	Few or no teams, no significant research product, total reliance on technology transfer/import.
IMPLEMENTATION FEASIBILITY	**(4) Ready to start**	Infrastructure is intact, regulatory framework exists. (AND) Necessary funding (domestic or donor) readily available.
	(3) Highly feasible / Low barrier	Minor investment in infrastructure and/ or minor legislation changes needed. Necessary funding is manageable within standard grant frameworks + domestic state/private.
	(2) High Barrier	Requires significant capital expenditure, e.g. for building new infrastructure from scratch, with investment sources yet to be found/negotiated; (OR) requires major legislative changes likely to cause a significant political resistance.
	(1) Prohibitive	Unrealistic given current post-war constraints, requires resources unavailable in the medium term.
EU ALIGNMENT	**(4) Direct Match**	Directly addresses a specific EU Mission, or Cluster.

INDICATOR	QUALIFIER LEVELS	ASSESSMENT CRITERIA
	(3) Strong Alignment	Fits well with general EU frameworks and/or challenges.
	(2) Neutral/Weak	Neither conflicts with nor specifically advances EU priority agendas (e.g., obsolete technologies to be phased out soon).
	(1) Conflicting	Directly contradicts EU regulations (e.g., violates the AI Act or environmental standards).
RISK LEVEL	**(4) Low risk**	Proven technology, clear path.
	(3) Medium risk	Some uncertainties but manageable within a well-estimated time period.
	(2) High risk	Significant technical/market uncertainties, time estimates unreliable.
	(1) Contingent/Dependent	Requires other fields to succeed first.

SECTION 3. INTEGRATED DESIGN: EU-ALIGNED FORESIGHT WITH PRIORITY MAPPING

Sections 1 and 2 of this work have established a methodological foundation by analyzing global best practices and defining a system of indicators to assess R&D potential. However, as prior research on foresight and policy implementation shows, some of foresight initiatives may lose traction not because of inaccurate forecasts, but because their outputs remain weakly coupled to decision-making routines and are not translated into visible policy or management action (Janzwood & Piereder, 2019; Priebe et al., 2025). If findings are not converted into visible management decisions, they risk remaining a purely academic exercise with no impact on real-world policy.

- Consequently, this section is dedicated to the transformation of the developed methodology into a roadmap (figure 3.1), namely:
- the development of an integrated framework linking missions with national strategic pillars and indicator systems;
- the implementation of a two-phase foresight process, comprising Phase 1 focused on mobilization, mission–pillar mapping, and the establishment of the assessment framework, and Phase 2 dedicated to parallel foresight activities, including Delphi assessment (Dalkey and Helmer, 1963; Linstone and Turoff, 1975), international validation, and alignment with EU policy instruments;
- the execution of Phase 3, aimed at the synthesis and consolidation of results, validation through international expert engagement, and the development of mission roadmaps, implementation mechanisms, and governance structures to ensure the translation of prioritized research directions into policy frameworks;
- the delivery of outputs, encompassing a set of evidence-based priorities, mission roadmaps, quality-of-life monitoring frameworks, operational partnership mechanisms, and governance structures, ensuring the practical implementation, monitoring, and management of the foresight results;
- the allocation of financial and institutional resources through a structured budget framework, supporting the coordinated execution of all phases;
- the identification and evaluation of advantages and limitations of the integrated design, assessing its implementation feasibility and potential risks, thereby supporting informed decision-making and further improvement of the approach;
- the definition of critical success factors, aimed at ensuring effective implementation through evaluator quality, platform robustness, international partner engagement, strong political and institutional commitment, and adaptive management throughout the process.

Figure 3.1. Strategic Workflow of the Integrated Foresight Process

INTEGRATED 9-MONTH PROCESS

Phase 1: Mobilization, Pillar Mapping & Framework Setup

Weeks 1–3:
• Formation of International Steering Council (5 countries).
• Mission Definition & Alignment with WINWIN Strategy.
• Assessment Framework Calibration (6 indicators, 4-point scales).

Weeks 4–6:
• Pillar Relevance Analysis (mapping to National Grand Challenges).
• Stakeholder Workshops (Health, Environment, Recovery).

Weeks 7–8:
• Assessment Platform Launch & Evaluator Training (150–200 experts).
• Formula Calibration (mission-specific k-coefficients).

Months 1–2

Phase 2: Parallel Foresight with Quantitative Assessment

Process A
Weeks 9–14:
• Quantitative scoring & Priority Graph generation.

Weeks 15–16:
• Discussion of divergence & synergies.

Weeks 17–22:
• In-depth assessment, risk analysis, and technology roadmapping.

Process B
Weeks 9–22 (continuous):
Continuous validation by Estonia, Denmark, Finland, UK, Norway.

Process C
Weeks 9–22 (continuous):
Monthly sessions with DG R&I, JRC, DG SANTE, DG ENV.

Months 3–6

Phase 3: Synthesis, Validation & Roadmapping

Weeks 25–27:
• Consolidation of results; categorization into Quick Wins and Strategic Bets.

Weeks 28–31:
• Development of 8 Mission Roadmaps (2027–2035) & Integrated Master Roadmap.

Weeks 32–36:
• Consolidated Report (300–350 pages).
• Establishment of Mission Steering Committees and International Advisory Board.

Months 7–9

KEY DELIVERABLES

Evidence-Based Priorities:
• 40–60 Validated R&D Priorities categorized by Impact vs. Readiness.
• 60% Focus on Quality of Life (Health, Environment, Recovery).
• Strategic Segmentation: Quick Wins (2027–28) & Strategic Bets (2028–30).

Mission Roadmaps (2027–2035):
• 8 Specialized Roadmaps with detailed action plans and timelines.
• Integrated Master Roadmap highlighting cross-mission synergies.
• Funding Mix: Clear split between National Budget & EU Co-financing.

Quality of Life Framework:
• Wellbeing Monitoring Dashboard aligned with EU Social Scoreboard.
• Standardized Indicators: 30+ metrics for Health & Environment resilience.
• Adaptive Triggers for regular policy updates based on real-time data.

Partnership & Funding Atlas:
• Twinning Portfolio: 15–20 institutional matches with EU partners.
• Horizon Europe Roadmap: 25–35 joint project pathways (Calls & Clusters).
• Mobility Network: 60–80 research exchange opportunities.

Post-Foresight Governance System:
• Institutional Setup: Active Mission Steering Committees.
• International Advisory Board for long-term strategic oversight.
• Calibrated Expert Network: 150+ trained national evaluators.

9 Months

PART 1: INTEGRATED FRAMEWORK DESIGN

The proposed design is grounded in the methodology elaborated in Section 2, in particular:

- **Mission-based structure** mapped to National Grand Challenges (Pillars), implemented through a Two-Tier Mapping Structure that aligns eight missions with grouped national priorities covering recovery and resilience, core societal needs, and advanced development domains;

- **Quantitative assessment** using 6 core indicators with 4-point scales, where each R&D direction is evaluated across strategic relevance, economic and reconstruction impact, social impact, R&D capacity (human dimension), implementation feasibility, and EU alignment, complemented by additional dimensions capturing the synergy-enabling effect, risk level, and international collaboration potential, ensuring assessment of both national significance and innovation readiness.

- **Priority Graph visualization** (Impact–Readiness matrix), where R&D directions are positioned based on composite Impact and Readiness scores, calculated as the average of key indicators, enabling their classification into four strategic quadrants (Quick Wins, Strategic Bets, Low Hanging Fruit, and Distractions) to support differentiated policy prioritization and resource allocation.

- **Driver-based stress testing**, whereby all prioritized R&D directions are systematically evaluated against key global and Ukraine-specific drivers—ranging from climate change, technological disruption, and war related needs to post-war reconstruction and EU accession requirements—through resilience-oriented questioning, complemented by cluster analysis and sensitivity testing to ensure robustness and minimize potential bias in prioritization outcomes.

In particular, based on analysis of Ukraine's strategic documents, legislative framework, national and sectoral development strategies, as well as key policy initiatives including the WINWIN Global Innovation Strategy 2030, the Sustainable Development Goals, and EU instruments such as the Ukraine Facility, a synthesis and systematization of the main priority areas was done. As a result of this analysis, the alignment between missions and their primary (core) and secondary (supporting) strategic pillars was established, reflecting an integrated vision of national development priorities in the context of post-war recovery and European integration.

Table 3.1. Mission-to-Pillar Alignment: Primary and Secondary National Strategic Priorities

Mission	Primary Pillars	Secondary Pillars
Health Mission	Health and Care	Sustainable Economy, Effective Government & Advanced Technology, Education
Environment Mission	Environment & Climate Adaptation	Food Security, Energy Security
Recovery Mission	Post-War Reconstruction	Energy Security, Food Security
Digital Mission	Advanced Technology, Effective Government	Defence & Security, Education
Dual-use Mission	Defense & Security	Advanced Technology, Sustainable Economy
Infrastructure Mission	Post-War Reconstruction	Regional Development, Sustainable Economy
Social Resilience Mission	Culture & National Identity, Education	Health & Care, Effective Government
Research Excellence Mission	Excellent Basic Science	Advanced Technology, Education

National Strategies: Laws and Regulations
Ukraine's WINWIN platform (https://winwin.gov.ua/en)[1]
Sustainable Development Goals: https://zakon.rada.gov.ua/laws/show/722/2019#n5
Ukraine Facility: https://zakon.rada.gov.ua/laws/show/244-2024-%D1%80#Text

Other relevant laws and sectoral strategies:
Science (Law): https://zakon.rada.gov.ua/laws/show/848-19
Climate (Law): https://zakon.rada.gov.ua/laws/show/3991-20#Text
Health Care (Law): https://zakon.rada.gov.ua/laws/show/2573-20#Text
Health Rehabilitation (Law): https://zakon.rada.gov.ua/laws/show/1053-20#Text
Mental Health (Law): https://zakon.rada.gov.ua/laws/show/4223-20#Text
Environmental Assessment (Law): https://zakon.rada.gov.ua/laws/show/2059-19#Text
Security (Law): https://zakon.rada.gov.ua/laws/show/2469-19#Text

Strategies:
Strategic Planning: https://zakon.rada.gov.ua/laws/show/853-2025-%D1%80#Text
Education and Science (Plans): https://mon.gov.ua/strategichniy-plan-diyalnosti-mon-do-2027-roku
https://zakon.rada.gov.ua/laws/show/1383-2025-%D1%80#Text
Higher Education: https://zakon.rada.gov.ua/laws/show/286-2022-%D1%80#Text
Demining: https://zakon.rada.gov.ua/laws/show/616-2024-%D1%80#Text
Defence City: https://zakon.rada.gov.ua/laws/show/1745-2025-%D0%BF#Text
Transport: https://zakon.rada.gov.ua/laws/show/1550-2024-%D0%BF#Text
Energy Security: https://zakon.rada.gov.ua/laws/show/907-2021-%D1%80#Text
Food Security: https://zakon.rada.gov.ua/laws/show/684-2024-%D1%80#Text
Maritime Security: https://zakon.rada.gov.ua/laws/show/1162-2024-%D1%80#Text
Culture: https://zakon.rada.gov.ua/laws/show/293-2025-%D1%80#Text

[2] Ukraine's WINWIN platform (https://winwin.gov.ua/en) is the country's Global Innovation Strategy until 2030, approved by the Government in January 2025. The strategy identifies 14 priority sectors including DefenceTech, MedTech, BioTech, GreenTech, EdTech, AgriTech, AI, XR, AUV, Semiconductors, Secure Cyberspace, SpaceTech, GovTech, and Fluid Economy.

Veterans: https://zakon.rada.gov.ua/laws/show/1350-2024-%D1%80#Text
Regional Development: https://zakon.rada.gov.ua/laws/show/940-2024-%D0%BF#Text

Building on the indicator-based assessment and multidimensional evaluation framework, the next step involves the integration of results into a unified priority scoring mechanism. This is achieved through mission-specific priority formulas, which assign differentiated weights to key indicators depending on the strategic nature of each mission, ensuring that the final prioritization reflects both contextual policy objectives and the functional role of R&D across domains:
For Health, Environment, Recovery Missions: R&D Capacity, Social Impact, and EU Alignment are equally relevant core priorities, whereas the Synergy Effect may be marginal.

Priority Score = Base Potential +
0.20 × Strategic Relevance & Economic Impact +
0.25 × R&D Capacity +
0.25 × Quality of Life & Social Impact +
0.25 × EU Alignment +
0.05 × Synergy Effect

For Digital, Dual-use Missions: Military/Dual-use Need is of the highest priority, followed by R&D Capacity and Strategic Relevance.

Other factors are secondary
Priority Score = Base Potential +
0.20 × Strategic Relevance & Economic Impact +
0.30 × Military/Dual-use Need +
0.25 × R&D Capacity +
0.10 × Quality of Life & Social Impact +
0.10 × EU Alignment +
0.05 × Synergy Effect

For Research Excellence, Infrastructure, Social Resilience Missions: R&D Capacity (here specifically measured as excellence in fundamental disciplines) is of the highest priority, followed by Quality of Life &Social Impact and EU Alignment, whereas the Synergy Effect may be marginal.

Priority Score = Base Potential +
0.10 × Strategic Relevance & Economic Impact +
0.35 × R&D Capacity (excellence in fundamental disciplines) +
0.30 × Quality of Life & Social Impact +
0.20 × EU Alignment +
0.05 × Synergy Effect

To ensure the external validity and practical applicability of the proposed framework, the selection of partner countries is conducted based on a set of clearly defined criteria:
1. European Integration Excellence: Track record in Horizon Europe participation, ERA implementation, and mission-based policy frameworks.

2. Post-Transition Experience: Relevant experience in research system transformation, particularly applicable to Ukraine's recovery context.

3. Bilateral Relationship Strength: Existing cooperation agreements, funding programs, and institutional partnerships with Ukraine.

4. Mission-Specific Expertise: Leadership in areas aligned with Ukraine's 8 missions (health, environment, digital, dual-use, etc.).

5. Methodological Capacity: Experience with foresight exercises, priority-setting frameworks, and quantitative assessment methodologies.

6. Political Commitment: Demonstrated long-term commitment to supporting Ukraine's European integration and reconstruction.

A set of five potential partner countries is identified below based on their overall alignment with the proposed criteria, reflecting a balanced combination of methodological expertise, sectoral strengths, and strategic relevance to Ukraine's priority missions. These countries demonstrate strong engagement with EU research and innovation frameworks and possess experience applicable to post-transition and recovery contexts. In addition, two equally viable alternative partners are presented, providing flexibility to adjust cooperation depending on specific mission requirements, evolving policy priorities, or the availability of institutional partnerships and funding mechanisms.

Estonia: Digital Transformation and Post-Soviet Success
Estonia is the premier example of successful post-Soviet research system transformation and digital government innovation. Estonia offers directly applicable lessons for Ukraine's recovery and modernization trajectory.
Key Strengths: Digital Leadership, Post-Soviet Transformation, Dual-Use Innovation, Existing Ukraine Partnerships.
Mission Alignment: Primary: Digital Mission, Dual-Use Mission. Secondary: Effective Government pillar, Research Excellence Mission (small country excellence model).

Finland: Innovation Excellence and Research Quality
Finland consistently ranks among the world's top innovation performers, with deep expertise in research excellence, mission-driven funding, and resilient systems design. Finland's experience in maintaining research competitiveness while managing Russia's pressures is particularly relevant to Ukraine's current situation.
Key Strengths: Research Excellence, Mission-Based Policy Expertise, Health Innovation, Resilience and Security, Ukraine Support.
Mission Alignment: Primary: Research Excellence Mission, Health Mission. Secondary: Social Resilience Mission, Digital Mission, all missions (methodological excellence).

Denmark: Green Transition and Quality of Life Focus
Denmark is a global leader in innovation, green technology, sustainable development, and quality of life innovation. Danish expertise is crucial for Ukraine's innovative and defence-tech solutions, as well as ambitious 60% resource allocation to Quality of Life missions, particularly in environment and climate adaptation.
Key Strengths: Green Technology Leadership, Mission-Driven Innovation Policy, Health and Social Innovation, Ukraine Innovation Cooperation.
Mission Alignment: Primary: Dual-Use and Defence Innovation, Environment Mission, Health Mission. Secondary: Infrastructure Mission (sustainable reconstruction), Social Resilience Mission, Recovery Mission.

United Kingdom: Research Excellence and Ukraine Partnership
The United Kingdom combines world-leading research excellence with deep political commitment to Ukraine's European integration in a broader sense. UK expertise in research assessment, dual-use technology, and large-scale innovation programs provides essential methodological and strategic guidance.
Key Strengths: Research Excellence Framework, Dual-Use and Defence Innovation, Strong Ukraine Partnership, Scale and Capacity.
Mission Alignment: Primary: Research Excellence Mission, Dual-Use Mission. Secondary: All missions (methodological expertise), Health Mission, Digital Mission.

Norway: Energy Expertise and Resource-Based Innovation
Norway brings unique expertise in energy security, resource management, and sustainable development from a resource-rich economy perspective. As a strong supporter of Ukraine with deep engagement through the Norwegian Research Council, Norway offers essential guidance for Ukraine's energy transition and recovery priorities.
Key Strengths: Energy Security and Transition, Resource Economy Management, Research Council Engagement, Environment and Climate Resilience.
Mission Alignment: Primary: Recovery Mission (energy security), Environment Mission. Secondary: Infrastructure Mission, Research Excellence Mission, all missions (reconstruction financing models).

Alternatives

Sweden: Innovation Systems Leadership and Baltic Region Connectivity

Sweden is one of Europe's foremost innovation and research economies, consistently ranking first or second in the European Innovation Scoreboard. As a leading Horizon Europe participant, a pioneer in sustainable industrial transformation, and a country with deep institutional ties to both the Baltic region and Ukraine, Sweden represents a highly strategic addition to the partner country configuration. Sweden's inclusion diversifies methodological expertise, and closes key mission coverage gaps, particularly in sustainable industry, defence innovation, and social cohesion policy.

Key Strengths: Innovation System Excellence, Sustainable Industrial Transition, Defence and Dual-Use Innovation, Digital and Data Infrastructure, Baltic and Nordic Regional Integration, Existing Ukraine Engagement.

Mission Alignment: Primary: Environment Mission, Dual-Use Mission, Research Excellence Mission. Secondary: Recovery Mission, Social Resilience, Digital, Infrastructure.

Netherlands: Horizon Europe Excellence and Systems Integration

The Netherlands is one of the top performers in Horizon Europe participation, with exceptional expertise in EU research integration, multi-stakeholder coordination, and systems-level innovation. Dutch experience in building competitive EU-aligned research systems is directly applicable to Ukraine's integration goals.

Key Strengths: Horizon Europe Excellence, Health Technology and Life Sciences, Complex Systems Coordination, Climate Adaptation and Water Technology.

Mission Alignment: Primary: All missions (EU integration expertise), Health Mission, Environment Mission. Secondary: Infrastructure Mission, Recovery Mission.

PART 2: INTEGRATED 9-MONTH PROCESS

The implementation of the proposed framework is structured as a nine-month process that combines institutional mobilization, analytical assessment, and international validation. The process is organized into two main phases, each integrating multiple parallel and interlinked activities to ensure methodological robustness, stakeholder engagement, and alignment with EU standards.

Phase 1: Mobilization, Pillar Mapping & Framework Setup (Months 1-2)

The first phase focuses on establishing the institutional, methodological, and analytical foundations necessary for the foresight exercise.

Phase 1 is structured into a sequence of interrelated stages that combine institutional mobilization, analytical framework development, and initial quantitative assessment. These stages are designed to ensure coherence between mission definition, indicator-based evaluation, and alignment with EU policy priorities, while simultaneously building the necessary expert capacity and digital infrastructure. The detailed structure, timeline, and key activities of Phase 1 are summarized in Table 3.2.

Table 3.2. Phase 1: Mobilization, Pillar Mapping & Framework Setup (Weeks 1–8)

Timeline	Component	Key Activities
Week 1–3	Dual Mobilization with Framework Design	International Steering Council Formation: 5 partner countries (Estonia, Denmark, Finland, UK, Norway; alternatives: Sweden, Netherlands) and EU experts (DG R&I, JRC, DG SANTE, DG ENV); launch of expert evaluator training program
		Mission Definition with Pillar Alignment: definition of 6–8 national missions aligned with WINWIN Strategy; mapping to primary and secondary pillars across Groups 1A, 1B, and 2; development of mission-to-EU alignment matrix; formation of 8 mission teams (15–20 experts each) and 5 international working groups
		Assessment Framework Calibration: agreement on 6 core indicators and 4-point scales; definition of evaluation criteria; evaluator training with calibration exercises (inter-rater reliability); development of an integrated online platform with automated scoring and visualization
Week 4–6	Diagnostic Analysis with Quantitative Mapping	Pillar Relevance Analysis: mapping missions to National Grand Challenges; identification of 10–15 R&D sub-directions per mission; preliminary assessment using 6 indicators applied across all 8 missions
		EU Acquis & Best Practices: alignment with Horizon Europe 2025–2027 strategic orientations (green, digital, resilient Europe), including biodiversity (10%) and climate expenditure targets; mapping to EU missions (Cancer, Climate, Soil, Ocean, Cities); benchmarking with partner countries; identification of twinning opportunities
		Stakeholder Workshops (3×2 days): Health (Denmark, Norway, UK); Environment (Finland, Norway); Recovery & Digital (Estonia, UK, Finland); framework presentation, preliminary scoring, and initial driver-based stress testing of priority areas
Week 7–8	Methodology Finalization	Assessment Platform Launch: deployment of integrated digital platform with automated scoring (4-point scales), dynamic Priority Graph generation, mission-specific formula implementation, and driver stress-test module
		Evaluator Training (Critical): 2-day intensive training for 150–200 experts; calibration exercises (inter-rater reliability); practice assessments with feedback; participation of international experts
		Formula Calibration: setting of mission-specific k-coefficients; pilot validation of scoring models; development of visualization templates (Priority Graphs)

In addition, the diagnostic and assessment activities are systematically applied across all defined missions, ensuring consistency and comparability of results. Particular emphasis is placed on alignment with Horizon Europe strategic orientations and the integration of driver-based stress testing at early stages of evaluation. The assessment process is further supported by calibration exercises to ensure inter-rater reliability and by the use of a digital platform enabling automated scoring and visualization. Pilot validation of scoring models ensures the robustness and applicability of the methodology prior to large-scale implementation.

Phase 2: Parallel Foresight with Quantitative Assessment (Months 3-6)

Phase 2 represents the core analytical stage of the integrated foresight process, combining large-scale expert evaluation with continuous international validation and alignment with EU policy frameworks. This phase is implemented through three parallel and interconnected processes—including mission-based Delphi assessment, international expert engagement, and an EU integration track—ensuring the robustness, comparability, and practical relevance of prioritization results. The structure, timeline, and key activities of Phase 2 are summarized in Table 3.3.

Table 3.3. Phase 2: Parallel Foresight with Quantitative Assessment (Months 3–6)

Process	Timeline	Component	Key Activities
A	Weeks 9–14	Mission Delphi with Integrated Scoring (Round 1)	Assessment conducted across all 8 missions using digital platform: identification of 10–15 R&D sub-directions per mission; quantitative scoring using 6 core indicators (4-point scales); narrative justification; driver resilience check (with explanation); EU alignment (link to Horizon Europe 2025–2027 calls); automated aggregation, real-time Priority Graphs, and consensus/divergence visualization
	Weeks 15–16	Interim Workshops (Futures Workshops)	8 online workshops (4 hours each): presentation of Round 1 Priority Graphs; discussion of divergent assessments; cross-mission synergies (Health–Environment; Digital–Dual-use; Recovery–Infrastructure); feedback from international working groups; refinement of assessment criteria
	Weeks 17–22	Delphi Round 2 (In-depth Assessment)	Focus on top-20 priorities per mission; detailed scoring with enhanced justification; risk assessment (4-point scale); synergy mapping; enhanced EU alignment (specific Horizon Europe calls, strategic orientations: green, digital, resilient Europe); identification of partnership opportunities; budget estimation (national vs EU co-funding); critical technology identification and technology roadmapping
B	Weeks 9–22 (continuous)	International Working Groups (5 groups)	Thematic validation and benchmarking (2 workshops per phase per group): Estonia (digital governance, cyber resilience; validation of Digital & Recovery missions); Denmark (dual-use innovation models; validation of Dual-use mission); Finland (green transition, quality of life; validation of Health, Environment, Recovery); UK (research excellence frameworks; horizontal validation across missions); Norway (sustainable development, biodiversity; validation of Environment & Infrastructure); outputs include validated Priority Graphs, policy-relevant benchmarks, and sector-specific recommendations
C	Weeks 9–22 (continuous)	EU Integration Track	Monthly online sessions with EU experts (DG R&I, JRC, DG SANTE, DG ENV); systematic mapping of priorities to Horizon Europe 2025–2027 calls; alignment with strategic orientations (green transition, digital transformation, resilient Europe); identification of 10–15 twinning opportunities; development of quality-of-life indicators; analysis of EU missions implementation

The implementation of Phase 2 is supported by a structured expert architecture and an integrated digital assessment environment to ensure analytical rigor and consistency. The Delphi process involves 150–200 national experts distributed across missions, with a minimum of approximately 25 experts per mission, ensuring statistically robust results. Depending on their expertise, individual experts may contribute to multiple missions, while each mission is complemented by 5–7 international experts acting as calibration anchors to enhance consistency and alignment with international best practices.

The assessment is conducted via an online platform enabling automated aggregation of scores, real-time visualization of consensus and divergence, dynamic generation of Priority Graphs, and anonymous peer comparison. Methodologically, the process follows a two-round Delphi logic, allowing iterative refinement and convergence of expert judgments through structured feedback.

Cross-mission workshops play a key role in identifying interdependencies and synergies between domains, while the integration of international working groups ensures continuous benchmarking and validation. In addition, the framework incorporates preliminary funding considerations, including national and EU co-financing mechanisms, and supports the development of technology roadmaps for high-priority areas, reinforcing the practical applicability of the prioritization results.

PART 3: SYNTHESIS, VALIDATION & ROADMAPPING (Months 7-9)

The third part of the integrated foresight process focuses on the synthesis of analytical results, their validation through international expertise, and the transformation into policy roadmaps and implementation mechanisms. This phase consolidates mission-level assessments into a coherent national framework, ensures alignment with EU priorities, and establishes the institutional and governance structures required for long-term implementation.

Table 3.4. Phase 3: Synthesis, Validation & Roadmapping (Months 7–9)

Timeline	Component	Key Activities
Weeks 25–27	Integration & Validation	Consolidation of results across all 8 missions; development of final Priority Graphs (Impact vs Readiness); categorization into Quick Wins (5–10 per mission) and Strategic Bets (3–8 per mission); cross-impact analysis (synergies, conflicts, sequencing); validation through 4 international expert panels (Health, Environment, Digital & Resilience, Innovation & Defence)
Weeks 28–31	Mission Roadmapping	Development of 8 mission roadmaps (2027–2035): structuring priorities by Priority Graph quadrants (Quick Wins, Strategic Bets, Long-term); definition of action plans, timelines, responsible institutions, and budget allocations; integration of EU co-funding strategies and partnership mechanisms; development of technology roadmaps and critical technology areas
		Preparation of 3 detailed priority roadmaps (Health, Environment, Recovery) and 5 standard roadmaps (other missions); development of an Integrated Master Roadmap (cross-mission synergies, governance, funding, monitoring framework)
Weeks 32–36	Finalization & Implementation Mechanisms	Preparation of consolidated report (300–350 pages), including methodology, EU integration strategy, mission results, and partnership atlas; validation through international panel; final endorsement of priorities and methodology
		Establishment of governance structures: Mission Steering Committees, International Advisory Board; deployment of Quality of Life monitoring dashboard; definition of annual review and adaptive prioritization mechanisms

Beyond the structured stages outlined in Table 3.4, Phase 3 would incorporate additional analytical, validation, and implementation elements that reinforce both the robustness and policy relevance of the foresight outcomes. In particular, the prioritization process results in a consolidated portfolio of approximately 40–60 R&D priorities across all missions, with a dominant share (60% of total) attributed to the Health, Environment, and Recovery domains, reflecting their central role in post-war recovery and quality-of-life improvements. A key analytical extension at this stage is the **cross-impact assessment**, which goes beyond individual priority evaluation by examining interdependencies between priorities through a synergy matrix. This enables the identification of enabling innovations, potential resource conflicts, and optimal sequencing pathways, ensuring that the final roadmap reflects systemic interactions rather than isolated interventions.

An essential component of the validation stage is the organization of **international expert panels**, each dedicated to specific mission domains and involving leading experts from partner countries alongside representatives of EU institutions. These panels play a critical role in validating Priority Graphs, confirming scoring consistency, and ensuring alignment with European policy frameworks and sector-specific best practices. The structure, thematic focus, and outputs of these panels are presented in Table 3.5.

Table 3.5. International Expert Panels for Validation (Phase 3)

Panel	Focus Area	Participants	Task	Key Focus	Output
Panel 1	Health & Wellbeing	Danish, Norwegian, British experts + DG SANTE	Validate Health mission Priority Graph and scoring	Alignment with EU health policy priorities	Endorsed priority list with EU alignment confirmation
Panel 2	Environment & Climate	Finnish, Norwegian experts + DG ENV	Validate Environment mission Priority Graph	Biodiversity target (10%), circular economy	Climate adaptation and circular economy priorities endorsed
Panel 3	Digital & Resilience	Estonian, British experts + DG R&I	Validate Digital and Recovery missions	WINWIN AI strategy, digital transformation	E-governance and cyber resilience priorities confirmed
Panel 4	Innovation & Defence	Danish, British experts	Validate Dual-use mission Priority Graph	Defense–civilian technology transfer	Dual-use innovation priorities approved

The development of **mission roadmaps** is significantly more detailed than reflected in the table, encompassing differentiated levels of granularity. In particular, the Health, Environment, and Recovery missions are supported by extended roadmaps (35–40 pages each), integrating quality-of-life indicators, detailed funding structures, and EU co-financing pathways. In contrast, other missions follow a more standardized structure while still incorporating core elements such as assessment scores, partnership mechanisms, and governance arrangements. All roadmaps include mandatory components such as full transparency of indicator scores, positioning within the Priority Graph, alignment with national pillars, results of driver-based stress testing, and explicit links to Horizon Europe calls.

In addition, a **Partnership and Funding Atlas** is to be developed, identifying 15–20 twinning opportunities, 25–35 joint project pathways linked to Horizon Europe calls, and a wide network of research exchange initiatives and institutional cooperation agreements. This ensures that prioritization outcomes are directly connected to implementable international collaboration mechanisms.

The final stage also places a strong emphasis on institutionalization and governance, which is essential for translating foresight results into long-term policy action. This includes the establishment of Mission Steering Committees for key domains, an International Advisory Board to ensure continuous external oversight, and the deployment of a Quality of Life monitoring dashboard with regularly updated indicators. These governance mechanisms are complemented by an annual review system, enabling adaptive prioritization based on evolving external drivers, implementation progress, and emerging policy needs.

Overall, these additional components ensure that Phase 3 moves beyond static prioritization to deliver a dynamic, system-based framework for implementation, monitoring, and continuous policy adaptation, fully aligned with both national recovery objectives and European integration trajectories.

PART 4: KEY DELIVERABLES (9 MONTHS)

Analytical results and validated priorities should be translated into a structured system of evidence-based policy instruments. These deliverables are designed to ensure transparency, measurability, and direct applicability for policy implementation, combining quantitative prioritization, mission-level roadmapping, monitoring frameworks, and operational cooperation mechanisms.

The deliverables outlined below (table 3.6) represent a fully operational framework that bridges the gap between foresight analysis and policy implementation. At the core of this output is a portfolio of 40–60 evidence-based priorities, derived through a rigorous quantitative assessment process that combines multi-criteria evaluation, mission-specific weighting, and visual prioritization using the Priority Graph methodology. The structured distribution of priorities across missions reflects both sectoral importance and national recovery needs, with a deliberate concentration on the Health, Environment, and Recovery domains.

Table 3.6. Evidence-Based Priorities (4.1)

Component	Description
Quantitative Foundation	6 core indicators (4-point scales); mission-specific weighted formulas; Priority Graphs (Impact vs Readiness)
Distribution Across Missions	Health (8–12); Environment (6–10); Recovery (5–8); Digital (4–6); Dual-use (4–6); Infrastructure (4–6); Social Resilience (3–5); Research Excellence (3–5)
Total Portfolio	40–60 priorities, of which 60% (24–35) in Health, Environment, Recovery
Categorization	Quick Wins (15–25); Strategic Bets (10–20); Long-term Exploration (5–10)

A key tool is mission roadmaps, which transform priorities into concrete actions with a clear time, financial, and institutional framework. The use of the Priority Graph logic ensures a transparent distinction between quick wins, strategic bets, and long-term goals. Attention is paid to the integration of EU funding, which provides not only resource support, but also deeper integration into the European Research Area.

Table 3.7. Mission Roadmaps (4.2)

Component	Structure	Content
Roadmap Types	3 priority (35–40 pp.); 5 standard (20–25 pp.); 1 integrated (50 pp.)	Differentiated depth and detail
Structure by Horizon	Quick Wins (2027–2028); Strategic Bets (2028–2030); Long-term (2030–2035)	Sequenced implementation logic
Core Elements	Assessment scores; Priority Graph position; pillar alignment; driver resilience; EU mapping (30–50 calls)	Full methodological transparency
Financing & Partnerships	Budget split: 60–70% national, 30–40% EU; twinning, COST, bilateral	Implementation readiness
Integrated Roadmap	Cross-mission synergies; governance; funding consolidation; monitoring system	System-level coordination

An important innovative component is the Quality of Life framework, which introduces a dimension of social impact into the evaluation system. Through a set of standardized indicators and a digital monitoring dashboard, it is possible to constantly track policy results and adapt them in accordance with changes in the external environment.

Table 3.8. Quality of Life Framework (4.3)

Component	**Description**
Conceptual Basis	Danish/Norwegian wellbeing models; aligned with SDGs and EU Social Scoreboard
Health Indicators (15–20)	Life expectancy; mental health access; trauma care; rehabilitation; equity
Environment Indicators (12–15)	Air/water quality; biodiversity (10% target); climate resilience; green space
Monitoring System	Quarterly updates; public reporting; baseline tracking; adaptive triggers

The operational dimension is complemented by a developed system of partnerships, which includes both institutional cooperation mechanisms (twinning, joint projects), and researcher mobility and the creation of common infrastructure. This ensures a direct connection between the identified priorities and the possibilities of their financing and implementation in an international context.

Table 3.9. Partnership Mechanisms (4.4)

Mechanism	Description
Twinning (15–20)	Institutions identified; MoUs; 3-year budgets
Joint Projects (25–35)	Horizon Europe aligned; €2–5M each; consortium structures
Research Exchanges (60–80)	Mobility programs; €3,000–5,000 per exchange
Institutional Agreements (8–10)	Joint labs, infrastructure, co-supervision; signed-ready

Finally, the established expert network and management system guarantee the sustainability of the process after the completion of the foresight phase. Through the activities of the Mission Steering Committees and the International Advisory Board, not only implementation monitoring is ensured, but also adaptive management, which allows adjusting priorities in response to new challenges.

Table 3.10. Expert Network & Governance (4.5)

Component	Description
National Experts (150–200)	Mission-based; calibrated; engaged in implementation
International Experts (50–70)	From partner countries; advisory and validation roles
Mission Steering Committees	Health, Environment, Recovery; quarterly decisions; mixed composition
International Advisory Board	12–15 members; annual strategic review; adaptive guidance

PART 5: BUDGET (9 MONTHS)

The implementation of the proposed foresight framework is supported by a structured and balanced budget combining national and international components. The total estimated cost of €810,000 reflects the comprehensive nature of the process, encompassing expert engagement, methodological development, digital infrastructure, and international validation activities. Detailed budget breakdowns, including cost allocation by activity, partner contributions, and co-funding scenarios, are provided in Annex D.

PART 6: ADVANTAGES & LIMITATIONS

The integrated design, while offering a framework for R&D prioritization, presents a combination of strengths and inherent limitations. These reflect the balance between analytical rigor, policy relevance, and implementation feasibility. The key advantages and limitations of the proposed approach are summarized in Table 3.11.

Table 3.11. Advantages of the Integrated Design

Dimension	Advantages
Scientific Rigor	Evidence-based assessment using standardized 6-indicator framework with 4-point scales; quantitative scoring reduces bias and increases transparency; evaluator training and calibration ensures quality; Priority Graphs provide clear visualization of trade-offs
EU Integration	Alignment with Horizon Europe Strategic Plan 2025–2027; focus on three strategic orientations: green, digital, resilient; 60% focus on Quality of Life (Health, Environment, Recovery); ready-to-implement partnerships (Twinning opportunities)
WINWIN Strategy Alignment	Direct connection to Ukraine's Global Innovation Strategy 2030; coordination with Centers of Excellence; integration with national AI development strategy; support for 14 priority sectors
International Legitimacy	Validation from partner countries and EU experts; best practices transfer (Estonia, Finland, Sweden, Denmark, UK, Netherlands, Italy); ongoing advisory support post-foresight
Governance	Mission-based structure easy to implement; Steering Committees for priority missions; International Advisory Board for oversight; Quality of Life monitoring dashboard operational
Adaptability & Resilience	Driver-based stress testing ensures resilience; Quick Wins vs Strategic Bets categorization enables phased implementation; annual review mechanism allows adaptive management; synergy mapping identifies cross-mission opportunities

While the advantages highlight the robustness and policy relevance of the proposed framework, it is equally important to acknowledge the inherent limitations that may affect its implementation and performance.

Table 3.12. Limitations of the Integrated Design

Dimension	Limitations
Complexity	8 missions + 5 international working groups require significant coordination; evaluator training critical; platform development and maintenance needed; intensive stakeholder engagement (150-200 experts)
Resource Intensity	Higher budget (€810,000); requires active cooperation from 5 partner countries; dependence on international expert availability; platform development and training costs
Timeline	9 months minimum (possibly 10–11); parallel processes require strong project management; validation cycles may extend timeline
Balance Concerns	Less emphasis on defense needs (dual-use present but not dominant); complexity may slow decision-making; requires sustained political commitment
Methodological Risks	Inter-rater reliability depends on evaluator training quality; formula weights are somewhat arbitrary; Priority Graph simplifies multi-dimensional assessment; driver stress testing subjective without quantitative models

Detailed suggestions for the risk management plan are shown in the Annex E.

PART 7: CRITICAL SUCCESS FACTORS

The effective implementation of the proposed integrated foresight framework depends on a set of critical success factors that ensure methodological quality, operational feasibility, and long-term policy relevance. These factors reflect the most sensitive elements of the design, where insufficient attention or errors can significantly affect the results of the entire process.

Table 3.13. Critical Success Factors

Factor	Elements
Evaluator Quality & Training	Intensive 2-day training for 150–200 national experts; specific training on 4-point scale assessment; calibration exercises with inter-rater reliability testing; practice assessments with feedback from international experts; ongoing support during assessment rounds; clear rubrics and examples for each qualifier level; monitoring of divergent assessments (red flags); expert panels to resolve major disagreements; international experts as calibration anchors; post-assessment debriefing to improve Round 2
Platform Robustness	Support for Delphi rounds with 150–200 concurrent users; 6-indicator scoring interface with 4-point scales (intuitive, mobile-friendly); automated aggregation and Priority Graph generation; real-time consensus/divergence visualization; anonymous peer comparison (optional); export functionality for analysis and reporting
International Partner Engagement	5 partner countries commit experts for 9 months; EU experts (DG R&I, JRC, DG SANTE, DG ENV) engaged early; clear terms of reference and deliverables for working groups; budget certainty for international travel and fees; MoUs signed before process begins
Political & Institutional Commitment	High-level political endorsement (ministerial level); alignment with WINWIN Strategy implementation; institutional buy-in from research councils, universities, agencies; budget security for 9 months; willingness to implement Quick Wins immediately; post-foresight governance structures resourced
Adaptive Management	Monthly steering committee reviews progress; adjust timelines if validation cycles slow down; add/remove Delphi questions based on Round 1 results; pivot to additional drivers if new threats emerge; scale resources dynamically between missions based on findings

The quality assessment and control framework is also briefly presented below in Annex F.

The suggested integrated design combines the strategic vision of EU-aligned mission-based foresight with the methodological rigor of quantitative evidence-based assessment using the revised 4-point scale framework. The result is a process that:

1. Produces 40-60 evidence-based priorities with clear categorization (Quick Wins, Strategic Bets).
2. Focuses 60% of resources on Quality of Life (Health, Environment, Recovery missions).
3. Aligns with Ukrainian strategic documents and EU planning process.
4. Enables rapid EU integration through alignment with three strategic orientations (green, digital, resilient).
5. Provides implementation roadmaps and post-foresight governance.

CONCLUSIONS

1. Crisis conditions demand phased, flexible priority-setting.

International experience confirms that research systems operating under conditions of war, a pandemic, or reconstruction pressures cannot rely on conventional multi-year planning cycles. The four-stage model presented in this study—War Mode, Reconstruction Mode, Innovation-Driven Growth, and Societal Resilience—offers a coherent sequential (although sometimes, under certain conditions, recurring) logic that reflects how nations have historically mobilised science under existential constraints. Each stage requires distinct governance instruments, funding mechanisms, and stakeholder configurations. Ukraine's current situation demands simultaneous activation of the first two stages while laying institutional foundations for the third.

2. The two-tier framework proposed in this study is mapping research directions first to National Grand Challenges and then scoring them against six weighted indicators. It provides the methodological rigour for practical action in priority setting. By separating strategic relevance, economic and social impact, R&D capacity (human dimension), implementation feasibility, and EU alignment into discrete measurable dimensions, the framework reduces the risk of politically driven or anecdotally justified prioritisation. The Priority Graph visualisation (Impact vs Readiness) translates the primary data into quadrant logic: Quick Wins, Strategic Bets, Low-Hanging Fruit, and Distractions.

3. International integration is not merely beneficial but structurally necessary for war-affected research systems.

The comparative analysis of nine countries including cases of economic transformation, post-war reconstruction models, and innovation-resilience leaders reveals that no country achieving strong research outcomes has done so in isolation. In Ukraine's case, EU alignment is simultaneously a strategic imperative and a funding lever. The proposed foresight design embeds EU alignment as a core indicator within the assessment framework, while the nine-month process architecture directly links priority identification to EU calls, twinning opportunities, and partnership mechanisms. This integration ensures that research priorities are credible not only domestically but also to international donors and scientific communities.

4. Quality-of-life missions must anchor the priority portfolio, not merely supplement defence and recovery objectives.

The evidence from countries navigating sustained crises consistently shows that maintaining research investment in health, environment, and social cohesion is not a luxury deferred until stability is restored. It is a condition for the stability itself. The substantial resource allocation to the Health, Environment, and Post-War Recovery missions proposed in this framework reflects this lesson directly. These missions are foundational to the demographic resilience, social trust, and institutional legitimacy upon which long-term recovery depends.

5. Governance quality and evaluator calibration support foresight validity.

The comparative analysis reveals that countries achieving the highest research impact, regardless of whether they used centralised or decentralised models, shared three characteristics: strategic coordination across ministries, active industry and stakeholder participation in priority formation, and robust institutional mechanisms for translating scientific excellence into economic value. In crisis conditions, this means that the process design of foresight exercises, including evaluator training, inter-expert calibration, and platform quality, increase outcome legitimacy.

6. The proposed framework can be extended beyond Ukraine and applied to other research systems facing existential threats.

While the framework was designed for and tested against Ukraine's specific war related context, its architecture combining a National Grand Challenges taxonomy, a multi-indicator scoring system, driver-based stress testing, and a staged foresight process is sufficiently modular for adaptation to other national contexts experiencing war, pandemic aftermath, or structural crises. The PESTLE-aligned indicator structure, the mission-to-pillar mapping logic, and the Priority Graph methodology are transferable tools. Future research should test the framework in additional war related or post-war contexts to validate its generalization and refine the indicator weights for different crises circumstances and institutional environments.

RECOMMENDATIONS FOR FORESIGHT IMPLEMENTATION

The following suggestions may be useful for agencies and organizations involved in foresight design and implementation.

Table 4.1. Linking Identified Challenges to Corresponding Recommendations

Challenges or risks	Recommendations
Complexity and Coordination Risks. Delayed start, lack of political buy-in, and risk of mid-process disruptions	• The foresight process should be launched as soon as possible, anchored in high-level political endorsement. • A dedicated Project Management Office (PMO) should be established in Month 1 with a full-time project manager and mission coordinators.
International Partner Engagement Risks	• Budget (including donor) commitments for international expert fees and travel should be finalised as soon as possible. If the funding is reduced, a contingency plan should be activated.
Evaluator Quality and Training Risks. Low inter-rater reliability, subjective bias, and lack of common assessment standards among evaluators	• Evaluator training and inter-rater calibration should be a priority. • A mandatory two-day calibration training for all evaluators before the first Delphi round should be done. • A tiered approach may be useful: train a core group of senior evaluators first, who then co-facilitate the broader training. • Examples for each level of the scales across all indicators will be helpful. • International experts from partner countries may serve as calibration anchors in the first Delphi round to anchor national assessors against externally validated benchmarks. • After Round 1, agreement for each indicator across assessors should be measured. If the agreement is detected as low, a re-calibration session should be done and an additional discussion should be organized until a better level of agreement is achieved. Cooperative interaction between national and international experts should be maintained through sustainable communication channels.

Challenges or risks	Recommendations
Timeline and budget constraints. Financial uncertainty, budget cuts, and rigid post-design fundraising tracking	• Co-funding mobilisation should be kept as a parallel track, not a post-design activity. • A contingency plan with a reduced budget is needed. • Contingency planning should be done in advance.
Risk of losing political and institutional commitment during long-term report preparation	• Implementation of Quick Wins projects may follow immediately and visibly to sustain political and institutional commitment. Quick Wins pilot projects should be selected with all reservations, based on a highly robust justification and on a "no regrets" basis. • By Month 6–7, the first portion of Quick Win priorities from the Health, Environment, and Recovery missions can be released with immediate budget allocation signals. The Health, Environment, and Recovery mission roadmaps are among the most consensus-ready and they may be prioritised for early release. • For Strategic Bets identified in the Priority Graph (high-impact directions with currently insufficient R&D capacity), some capacity-building investments may be made before or during the final report delivery.
Lack of operational tracking infrastructure and high institutional burden from monitoring	• The monitoring and governance infrastructure should be established as first-class deliverables. • Mission Steering Committees (Health, Environment, Recovery) and the International Advisory Board may be established by Month 7, so that governance structures are operational before the final report is delivered. • The Quality of Life monitoring dashboard may be presented as an operational prototype. The dashboard may track, e.g., 10-15 indicators by area on a quarterly basis, drawing on existing administrative data streams to minimise survey burden. Early warning indicators will be especially beneficial.
Rapidly changing external conditions, shifting security landscapes, and high strategic uncertainty	• The first adaptive priority review may be done at 18–24 months after delivery. At that review, the driver stress test should be run against updated assumptions about the security situation, reconstruction pace, and EU accession timeline, as well as technological, economic and societal developments. Ideally, this may be complemented by ongoing monitoring with regular short interim updates.

Overall, transparency, flexibility, multiple ways of feedback collecting and quality assessment are important for the foresight implementation in rapidly changing conditions with high uncertainty.

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ANNEXES

ANNEX A

Table A.1. Dynamics of the positions of the analyzed countries in the Global Innovation Index (GII)

Country (with ISO code)	Rank 2007	Rank 2018	Rank 2022	Rank 2025
Sweden (SE)	12	3	3	2
United Kingdom (GB)	3	4	4	6
Finland (FI)	13	7	9	7
Netherlands (NL)	9	2	5	8
China (CN)	29	17	11	10
Germany (DE)	2	9	8	11
Estonia (EE)	31	24	18	16
Italy (IT)	24	31	28	28
Türkiye (TR)	45	50	37	43

Source: Dutta & Caulkin (2007), Cornell University et al. (2018), WIPO (2022, 2025a).

ANNEX B

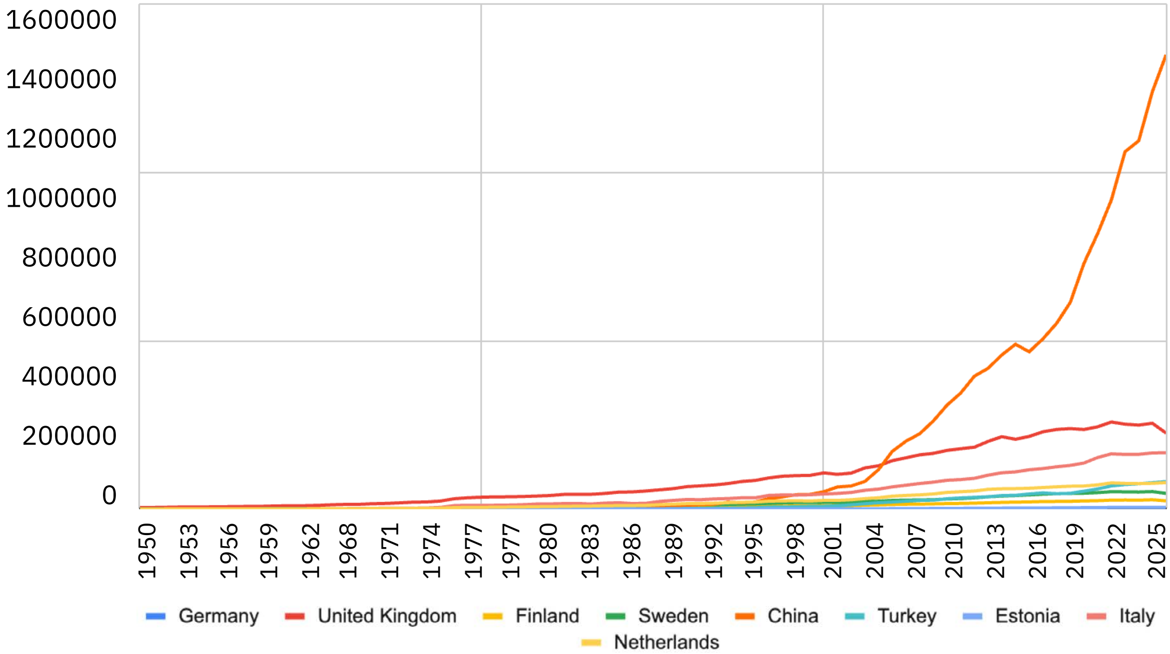

Figure B.1. Dynamics of countries' scientific productivity by the number of publications in the scopus database (1950–2025)
Source: Scopus

Table B.1. Comparative analysis of the structural transformation of countries' scientific fields by the number of publications in the S copus database for the periods 1950–2000 and 2001–2025

Subject area	UK		DE		FI		SE		CH		TR		EE		IT		NL	
	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025	1950-2000	2001-2025
Agricultural and Biological Sciences	5.2	3.6	4.2	3.7	5.2	5.1	4.5	4.4	2.0	3.8	4.4	5.0	6.8	7.2	3.2	4.0	5.1	3.9
Arts and Humanities	3.0	5.3	1.2	2.3	1.2	3.1	1.2	2.4	0.3	0.4	0.6	1.8	1.7	5.6	0.7	2.6	1.7	3.1
Biochemistry, Genetics and Molecular Biology	10.4	6.3	10.7	7.2	11.5	6.2	14.5	7.7	4.5	5.8	6.6	5.1	10.4	6.0	12.0	7.5	12.3	7.2
Business, Management and Accounting	1.3	2.6	0.3	1.5	0.5	2.9	0.4	2.0	0.5	0.8	0.6	1.7	0.2	2.2	0.2	1.5	0.5	2.1
Chemical Engineering	1.5	1.7	2.6	2.6	1.8	2.1	1.5	2.0	3.3	4.2	2.8	2.6	2.5	1.7	1.7	2.2	2.0	1.8

Subject area	UK		DE		FI		SE		CH		TR		EE		IT		NL	
Chemistry	5.1	3.2	9.2	5.5	4.0	3.6	4.8	4.0	9.1	6.8	6.7	4.7	7.8	3.9	6.5	4.0	6.6	3.1
Computer Science	2.3	5.8	2.4	7.2	3.2	8.8	1.9	6.0	4.8	9.5	3.0	5.9	2.3	7.7	2.6	7.2	2.8	6.0
Decision Sciences	0.4	0.8	0.3	0.7	0.4	1.0	0.3	0.7	0.2	1.0	0.5	0.8	0.2	0.9	0.2	0.8	0.5	0.9
Dentistry	0.4	0.4	0.1	0.3	1.1	0.4	1.1	0.5	0.1	0.1	0.8	0.9	0.0	0.1	0.2	0.4	0.4	0.3
Earth and Planetary Sciences	3.2	3.2	2.1	3.4	2.6	3.2	2.3	2.9	4.7	3.3	3.0	2.0	7.7	4.1	2.4	3.5	2.8	3.4
Economics, Econometrics and Finance	0.8	2.0	0.2	1.2	0.4	1.6	0.4	1.4	0.1	0.5	0.4	1.3	0.2	1.4	0.3	1.3	0.7	1.7
Energy	0.7	1.5	0.7	1.7	0.5	1.9	0.6	2.0	2.4	3.5	1.6	2.3	1.8	2.7	0.7	1.8	0.7	1.4
Engineering	7.3	8.0	7.3	9.9	6.3	10.0	5.6	8.8	17.4	17.5	8.9	10.3	6.5	9.7	6.2	9.8	6.3	7.5
Environmental Science	2.9	3.2	2.0	2.9	3.8	4.7	2.8	4.3	2.2	4.1	4.0	3.7	5.8	5.5	1.7	3.3	3.0	3.7
Health Professions	0.8	1.0	0.6	0.6	0.9	0.8	1.1	1.0	0.1	0.3	0.4	1.0	1.1	0.6	0.4	0.7	0.7	0.9
Immunology and Microbiology	2.8	1.8	2.1	1.9	3.3	1.7	3.7	2.3	0.7	1.4	1.6	1.3	2.1	1.5	2.6	1.9	3.6	2.3
Materials Science	4.3	3.7	6.5	6.3	3.7	4.6	3.9	4.6	12.4	9.1	5.4	5.5	6.5	4.1	4.5	4.3	4.4	3.4
Mathematics	2.7	3.4	4.0	4.5	2.8	4.0	2.4	3.3	6.2	5.2	3.3	4.3	3.4	3.9	3.5	4.8	3.1	3.3
Medicine	24.2	17.8	23.8	15.5	29.3	13.2	28.8	17.9	9.4	8.2	30.6	22.1	11.5	7.9	31.6	18.5	23.2	21.0
Multidisciplinary	0.8	1.3	0.3	1.3	0.3	1.2	0.5	1.6	0.6	1.1	0.1	0.6	0.2	1.3	0.3	1.0	0.4	1.4
Neuroscience	2.0	2.1	2.0	2.1	2.7	1.7	3.1	2.1	0.5	0.9	1.4	1.3	2.1	1.1	2.6	2.0	2.4	2.4
Nursing	1.0	1.6	0.5	0.6	0.8	1.1	0.6	1.3	0.1	0.3	0.2	1.1	0.2	0.5	0.4	0.7	0.6	1.1
Pharmacology, Toxicology and Pharmaceutics	2.6	1.4	3.2	1.5	3.3	1.2	3.3	1.6	2.5	1.8	3.7	1.7	3.0	1.1	3.7	1.9	3.1	1.6
Physics and Astronomy	6.9	5.8	11.2	9.5	6.7	6.6	7.2	6.9	15.1	8.5	6.9	5.8	12.4	7.3	10.5	8.0	8.1	5.8
Psychology	1.5	2.4	0.7	1.5	1.0	1.7	1.0	1.5	0.1	0.3	0.4	1.1	0.8	1.5	0.6	1.3	1.4	2.7
Social Sciences	5.3	9.7	1.2	4.4	2.2	7.7	1.8	6.6	0.7	1.8	1.4	5.4	2.7	10.3	0.9	4.6	2.8	7.5
Veterinary	0.6	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.1	0.2	0.9	1.0	0.3	0.4	0.2	0.5	0.8	0.5

Source: [Scopus]

ANNEX C

Table C.1. Comparative analysis of patent application-to-grant conversion rates for selected countries, % (1995–2024)

Country	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024
Germany	34.7	23.7	28.3	23.1	22.1	27.9	36.0	41.2	38.1	40.4
United Kingdom	34.4	25.2	36.3	25.5	24.0	47.3	57.8	54.3	42.0	43.4
Netherlands	25.0	94.2	83.3	70.4	55.2	63.2	65.2	74.6	111.6	86.3
Finland	61.9	66.8	85.3	50.4	65.7	35.7	32.8	46.8	33.6	32.3
Sweden	31.7	41.9	64.6	54.1	36.6	69.9	32.7	36.7	37.4	39.4
Italy	106.9	57.0	59.3	165.6	73.8	83.1	65.5	79.7	86.8	74.5
Estonia	0.0	10.4	428.9	123.7	66.7	52.2	30.8	60.0	40.6	53.3
Türkiye	45.1	33.4	71.8	0.0	29.5	25.3	40.0	37.8	28.0	32.8
China	18.1	25.2	30.8	34.5	32.6	35.4	43.9	49.3	54.9	57.2

Source: [WIPO IP Statistics Data Center]()

Table C.2. Distribution of published patent applications by technology fields in 1995 and 2022

Technology Field	Year	China	Estonia	Finland	Germany	Italy	Netherlands	Sweden	Turkiye	UK
ICT	1995	9.82	5.33	12.16	7.53	4.13	8.38	11.91	8.03	13.35
	2022	26.93	0.00	17.90	11.42	8.51	9.99	11.74	14.99	25.29
Electrical Engineering	1995	12.08	4.00	7.92	17.69	11.63	10.83	12.76	7.74	17.37
	2022	20.56	18.18	15.08	26.61	10.49	14.73	15.80	12.01	17.49
Chemistry & Materials	1995	25.72	34.67	21.72	15.34	11.40	11.25	9.66	35.08	12.14
	2022	13.42	22.73	15.31	5.45	8.86	9.13	11.21	10.81	6.84
Mechanical Engineering	1995	22.04	22.67	30.13	39.88	45.44	39.78	38.46	29.77	31.46
	2022	20.91	31.82	26.86	43.57	40.39	34.08	37.25	30.34	22.71
Medical & Biology	1995	12.47	21.33	15.92	5.38	6.73	6.40	9.79	6.04	7.60
	2022	8.03	18.18	8.13	3.69	9.68	11.09	6.18	13.40	9.58
Consumer Goods	1995	12.79	2.67	5.19	5.98	12.60	8.71	7.48	7.81	8.62
	2022	3.82	0.00	6.24	4.47	14.18	9.70	7.41	13.49	8.26

Technology Field	Year	China	Estonia	Finland	Germany	Italy	Netherlands	Sweden	Turkiye	UK
Environmental tech.	1995	1.45	2.67	1.78	2.19	1.54	3.34	2.61	2.21	1.45
	2022	2.32	4.55	2.71	1.34	1.67	2.95	1.68	1.44	1.46
Civil engineering	1995	3.62	6.67	5.18	6.02	6.53	11.30	7.32	3.32	8.01
	2022	4.01	4.55	7.77	3.44	6.22	8.34	8.74	3.51	8.36

Source: WIPO IP Statistics Data Center

ANNEX D

Projected budget plan for the rapid foresight on research priority setting (the case of Ukraine)

National Component: €410,000

Item	Cost (EUR)
Coordination (mission structure, project management)	€50,000
National expert honoraria (150-200 experts, assessment work)	€200,000
Online platform (Delphi, scoring, AI tools, Priority Graph generation)	€30,000
National workshops (stakeholder, futures, consolidation)	€50,000
Mission teams operation (8 teams, travel, materials)	€80,000
Subtotal National	**€410,000**

International Component: €400,000

Item	Cost (EUR)
International expert fees (5 countries, workshops, validation)	€150,000
Working groups coordination (5 groups, 2 workshops each)	€50,000
Travel and accommodation (international experts to Ukraine)	€50,000
EU experts engagement (DG R&I, JRC, DG SANTE, DG ENV)	€50,000
Translation/interpretation services	€50,000
International validation events (4 panels + final review)	€50,000
Subtotal International	€400,000

TOTAL BUDGET: €810,000

Co-funding Potential (35-45%): €320,000-400,000

Source	Amount (EUR)
Horizon Europe preparatory actions	€150,000-200,000
UK bilateral (Ukraine support programs - UK DIGIT)	€70,000-90,000
Norwegian Research Council	€50,000-70,000
Danish innovation cooperation	€40,000-50,000

ANNEX E

Risk Mitigation Plan
1. Complexity and Coordination Risks

Risk Description
The integrated design involves 8 missions, 5 international working groups, and 150-200 experts. This complexity creates substantial coordination challenges and potential bottlenecks.

Risk Factor	Probability	Impact	Priority
Multi-stakeholder coordination failure	High	High	**Critical**

Mitigation Strategies:
• Establish dedicated Project Management Office (PMO) with experienced project manager
• Deploy collaborative platform with mission-specific workspaces
• Implement two-weekly coordination meetings with clear agenda templates and decision logs
• Create escalation protocols for resolving bottlenecks
• Assign dedicated coordinators to each of the 8 missions and 5 international working groups

Contingency Plan:
If coordination challenges persist after Month 2, consolidate from 8 to 6 missions by merging Social Resilience into Recovery Mission and Infrastructure into Digital Mission. Reduce international working groups from 5 to 3 core countries.

2. Evaluator Quality and Training Risks

Risk Description
The quality of the entire foresight depends on well-trained evaluators. Poor inter-rater reliability or inadequate understanding of the 4-point scales could invalidate results.

Risk Factor	Probability	Impact	Priority
Low inter-rater reliability	Moderate	High	High
Inadequate training	High	High	**Critical**

Mitigation Strategies:
• Conduct intensive 2-day training for all evaluators with international expert facilitators. This may be done as a two-staged process. First, the core team trains a smaller team of evaluators, who will later assume senior-level roles inside evaluator teams (quality checks, helping the PM with lower-level management, and answering questions from evaluators). Second stage, those senior evaluators help the core team to train the rest of evaluators.
• Develop rubrics with specific examples for each level of the 4-point scales
• Implement calibration exercises using pilot R&D directions before main assessment
• Measure inter-rater reliability after Round 1 and provide targeted feedback to divergent assessors
• Establish expert panels to resolve major disagreements (threshold: >1.5 points difference on 4-point scale)
• Create ongoing support helpdesk available throughout assessment period

Contingency Plan:
If inter-rater reliability remains low after Round 1, extend the timeline by 2-3 weeks for additional training rounds and discussions until the level of agreement rises to an acceptable extent or consensus.

3. International Partner Engagement Risks

Risk Description
The design requires active participation from 5 partner countries plus EU experts over 9 months. Expert availability or funding constraints could disrupt this engagement.

Risk Factor	Probability	Impact	Priority
Partner country withdrawal	Low	High	**Medium**
Expert unavailability	Moderate	Moderate	**Medium**

Mitigation Strategies:
• Sign Memoranda of Understanding (MoUs) with the partner countries as soon as possible
• Secure budget commitments upfront for international expert fees and travel
• Identify backup experts from each partner country (minimum 2 alternates per working group)
• Schedule key workshops 4-6 months in advance to secure expert calendars
• Establish hybrid participation options (virtual + in-person) to maximize flexibility
• Engage partner country research councils and ministries to ensure institutional backing

Contingency Plan:
If one or two of partner countries withdraw, redistribute responsibilities to remaining countries and recruit replacement partners or experts. If three or more countries withdraw and have no replacement, pivot to primarily EU expert engagement (JRC) supplemented by individual experts from original partner countries.

4. Timeline and Resource Constraints

Risk Description
The 9-month timeline is ambitious given the scope. The budget of €810,000 requires securing €320,000-400,000 in co-funding. Delays or funding shortfalls could derail the entire process.

Risk Factor	Probability	Impact	Priority
Timeline slippage	High	Moderate	**High**
Co-funding shortfall	Moderate	High	**High**

Mitigation Strategies:
• Build 3-week buffer into timeline (extend to 11 months if needed)
• Pursue co-funding applications immediately (e.g., UK DIGIT, Norwegian Research Council, Danish Innovation)
• Identify priority activities that can proceed even with reduced co-funding (focus on Delphi rounds and priority missions)
• Establish monthly budget review checkpoints with steering committee
• Plan parallel work streams (mission assessments + international validation) to compress timeline

Contingency Plan:
If co-funding only reaches €200,000 (not €320,000+), reduce scope by focusing on 6 core missions (Health, Environment, Recovery, Digital, Dual-use, Research Excellence) and 3 partner countries. Reduce international travel and conduct more validation virtually. If timeline extends beyond 11 months, implement phased delivery with Quick Wins released at Month 6-7.

5. Platform and Technology Risks
Risk Description

The online platform must support 150-200 concurrent users for Delphi rounds with complex 6-indicator scoring. Technical failures or poor user experience could undermine data quality.

Risk Factor	Probability	Impact	Priority
Platform downtime during Delphi	Low	High	**Medium**
Poor user experience	Moderate	Moderate	**Medium**

Mitigation Strategies:
• Conduct load testing with 250 simulated users before Delphi Round 1 launch
• Ensure platform is mobile-friendly (tablet/smartphone compatible) for flexibility
• Conduct user acceptance testing with 20-30 pilot users before full rollout
• Prepare backup data collection method (offline forms) that can be deployed within 24 hours if platform fails

• Build automated backup systems with 4-hour data recovery capability

Contingency Plan:
If the platform experiences major failure during Delphi Round 1, extend the round by 1 week and switch to offline forms (Excel templates) with manual data aggregation. If user experience issues persist despite testing, simplify the interface by reducing real-time visualization features and focusing on core assessment functionality.

6. Methodological Validity Risks
Risk Description
Formula weights and the 4-point scale system are somewhat arbitrary and may not accurately capture priorities. Priority Graph simplification could mask important nuances.

Risk Factor	Probability	Impact	Priority
Arbitrary formula weights	Moderate	Moderate	**Medium**
Over-simplification in Priority Graph	Low	Low	**Medium**

Mitigation Strategies:
• Validate formula weights through sensitivity analysis after Round 1 (test alternative weighting schemes)
• Engage methodological experts (from partner countries) to review assessment framework before launch
• Conduct pilot assessments on 5-10 R&D directions to test validity and refine if needed
• Complement Priority Graph with detailed multi-dimensional profiles for each R&D direction
• Provide raw data access to stakeholders for custom analysis beyond Priority Graph
• Document all methodological decisions transparently in technical appendix

Contingency Plan:
If sensitivity analysis reveals formula weights significantly alter priorities, convene an expert panel to adjust weights based on national strategic objectives and rerun calculations. Also, additionally use stress tests.

7. Political and Institutional Commitment Risks

Risk Description
Success requires sustained high-level political support and institutional buy-in over 9 months. Changes in government priorities could undermine the process.

Risk Factor	Probability	Impact	Priority
Loss of political support	Low	High	**Medium**

Mitigation Strategies:
• Secure ministerial-level endorsement before launch with public announcement
• Establish high-level Steering Committee with representation from key ministries and research councils
• Conduct stakeholder engagement workshops with universities, research institutes, and agencies in Month 1
• Produce early Quick Wins (by Month 6-7) to demonstrate value and build momentum. Quick Wins pilot projects should be selected with all reservations, based on a highly robust justification and on a “no regrets” basis.
• Regular progress communications to Cabinet and Parliament highlighting EU alignment benefits
• Align foresight delivery timeline with key policy windows (budget cycles, strategic planning periods)

Contingency Plan:
If political support weakens, accelerate delivery of Health, Environment, and Recovery mission priorities (the most consensus-driven areas) and present these as standalone deliverables. If institutional resistance emerges, convene special consultation sessions to address concerns and adjust governance structure to increase institutional representation in decision-making.

8. Risk Related to Monitoring and Review Process

Monthly Risk Reviews:

The Project Management Office will conduct formal risk reviews at each monthly steering committee meeting. Risk register will be updated with current probability and impact assessments, and mitigation actions will be reviewed for effectiveness.

Key Milestones for Risk Assessment:

- Month 1: After evaluator training (assess quality and readiness)
- Month 3: After Delphi Round 1 (assess inter-rater reliability and platform performance)
- Month 5: Mid-point review (comprehensive assessment of all risk areas)
- Month 7: After priority formulation (assess methodological validity)
- Month 9: Final delivery (assess outcomes and capture lessons learned)

ANNEX F

Quality Assessment and Control Framework for Research Foresight Implementation

Real-Time Quality Control Mechanisms

The success of evidence-based foresight depends critically on its methodological rigour. Drawing from systematic review methodology and expert elicitation best practices, quality control must be embedded at multiple checkpoints.

Inter-rater reliability testing forms the foundation of assessment validity. Research on Delphi methods demonstrates that expert panels without calibration show correlation coefficients below 0.6, while trained panels achieve 0.75-0.85. The framework should implement Cohen's kappa statistics after Round 1, with mandatory recalibration workshops if agreement falls below 0.7.

Consensus monitoring should employ automated divergence detection. When expert scores on any indicator vary by more than 2 points on the 4-point scale, the platform triggers structured dialogue protocols. Anonymous peer comparison may be effective in reducing extreme outlier scores while preserving diversity of perspectives.

Methodological auditing requires independent statistical validation at key milestones. After each Delphi round, an external methodologist should verify: (1) response rates exceed 60% threshold for statistical validity, (2) non-response bias analysis using early-late responder comparison, (3) sensitivity analysis showing formula weight variations of ±10% don't fundamentally alter priority rankings.

Post-Implementation Monitoring Framework

The transition from foresight to implementation requires structured performance tracking.

Milestone-based progress tracking should employ a three-tier monitoring cadence. Quick Wins require bi-monthly progress reports against pre-specified 6-month milestones, using traffic-light dashboards (green/amber/red). Strategic Bets demand quarterly deep-dive reviews examining capacity-building progress, partnership activation, and funding pipeline development. Annual strategic reviews assess overall portfolio balance and emerging priority adjustments.

Counterfactual analysis becomes essential by Year 3. For each funded priority, monitoring should compare actual outcomes against baseline projections, explicitly documenting: publications in target journals, patent applications, successful Horizon Europe proposals, trained researchers, operational partnerships.

Adaptive priority adjustment requires formal scenario review at 18-24 months. Initial driver assumptions (climate trajectories, EU accession timeline, reconstruction pace, security environment) should be reassessed using structured horizon scanning. If reality deviates significantly from baseline scenarios, the Priority Graph should be recalculated with updated weights.

Quality of Life Indicators: From Theory to Measurement

The emphasis on Health and Environment missions demands wellbeing metrics. The OECD Better Life Index and Eurostat Quality of Life framework provide validated measurement architectures, but adaptation to military contexts requires methodological adjustments.

Composite indicator construction should follow the European Commission's Joint Research Centre guidelines for indicator development: (1) conceptual framework defining dimensions, (2) data quality assessment, (3) multivariate analysis to check structural validity, (4) sensitivity analysis for weighting schemes, (5) transparency in aggregation methods. For Ukraine's context, this means disaggregating by war-affected regions, accounting for displacement effects, and incorporating trauma-informed health metrics validated in post-war settings.

Quarterly monitoring practicality depends on leveraging existing administrative data streams rather than expensive bespoke surveys. Health indicators should tap hospital discharge databases, mental health service utilization, rehabilitation completion rates. Environmental metrics can utilize satellite remote sensing for air quality, water monitoring networks, biodiversity monitoring networks. The dashboard should explicitly note data quality limitations.

Improvement Mechanisms: Learning While Doing
Implementing effective research policy heavily relies on organizational learning capabilities, which this framework operationalizes through three distinct improvement loops:

Rapid response protocols address urgent deviations. If any Quick Win shows red status for two consecutive reviews, a mandatory weekly diagnostic review convenes mission steering committee, implementing institution, and international advisor. Root cause analysis using fishbone diagrams identifies whether failures stem from political obstacles, capacity gaps, funding delays, or partnership breakdowns. Corrective action plans prevent small problems cascading.

Annual strategic reviews enable systematic portfolio optimization. Each review should: (1) analyze success/failure patterns across missions using comparative case methodology, (2) assess whether resource allocation produced expected quality of life gains, (3) benchmark progress against partner country trajectories, (4) update driver assessments and conduct scenario stress-testing, (5) recommend priority additions/deletions with explicit evidence justification. The review outputs feed into budget cycle, ensuring alignment between strategic learning and resource allocation.

International peer review at Years 3 and 5 provides external validation. Panel reports rate each priority on original assessment dimensions, creating longitudinal data on whether initial projections proved accurate.

Governance Integration: Embedding Quality Control
Effective monitoring requires clear institutional homes and decision rights. The Mission Steering Committees (Health, Environment, Recovery) should receive quarterly performance dashboards with authority to reallocate 10-15% of mission budgets based on evidence. The International Advisory Board conducts annual meta-reviews with power to recommend strategic redirections to ministerial level.

Data infrastructure. A centralized research information system should integrate: publication databases (Web of Science, Scopus), funding records, international collaboration agreements, patent filings, trained personnel, infrastructure acquisitions. APIs to European systems (OpenAIRE, CORDIS) enable automated benchmarking. This digital backbone transforms monitoring from bureaucratic burden to strategic intelligence.

The framework's power lies in coupling assessment with accountability. By treating the Priority Graph as a dynamic management tool, Ukraine can demonstrate to EU partners and donors the evidence-based stewardship essential for sustained international support. The methodology suggested here offers "productive uncertainty": sufficient structure for accountability, sufficient flexibility for learning.

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