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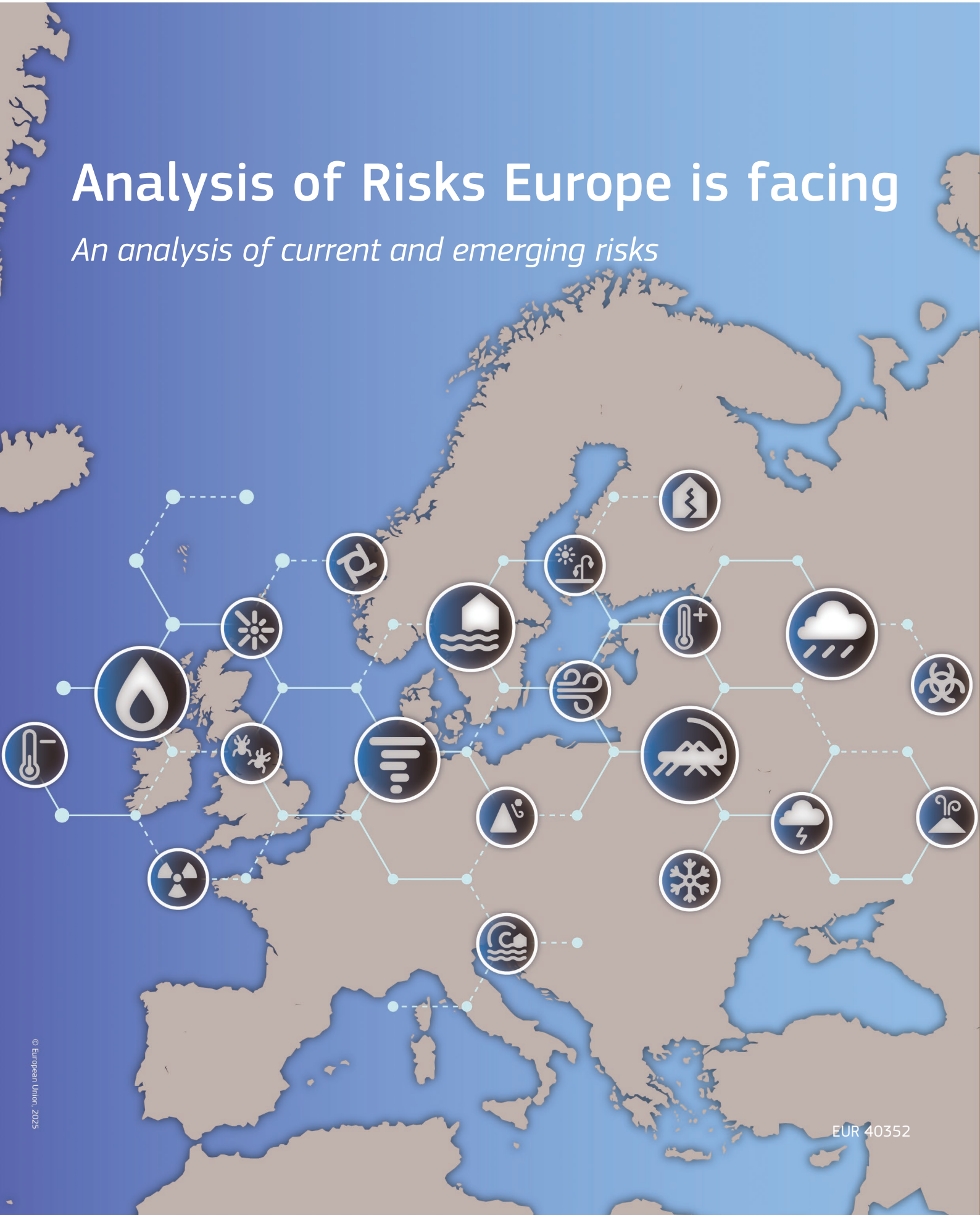
Analysis of Risks Europe is facing

An analysis of current and emerging risks



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Analysis of Risks Europe is facing

An analysis of current and emerging risks

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Foreword

As Europe stands at the nexus of intensifying global uncertainties, this flagship report on Current and Emerging Risks in Europe marks a critical step in shaping a more prepared and resilient Union. It offers an integrated scientific analysis of 47 diverse risks-from climate-driven disasters and pandemics to cyber threats and geopolitical instability-highlighting the urgent need for cross-sectoral, whole-of-society action.

Our Member States rightly expect the European Union to anticipate risks and threats and protect them from cascading crises through a coordinated and proactive approach to addressing the evolving risk landscape.

From rising temperatures and floods to disinformation campaigns and systemic technological disruptions, the nature of risk has evolved. Risks no longer occur in isolation-they intersect, compound, and ripple through societies and economies with far-reaching consequences. The challenges we face transcend borders demanding a unified, forward-looking response.

That is why the European Commission and the High Representative presented the EU Preparedness Union Strategy. This report provides scientific underpinning that could be used to develop its first key action: a comprehensive EU-level risk and threat assessment. In doing so, it also supports broader policy frameworks, including the Union Civil Protection Mechanism and its Disaster Resilience Goals as well as the European Climate Adaptation Strategy.

The journey towards the publication of the report has benefited from a strong collaborative effort between the Joint Research Centre (JRC) and the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO), reflecting the need to closely integrate science and policy to address today's complex risk landscape. The JRC played a vital role in delivering the science behind this vision. The JRC continues to translate complex data into actionable foresight. Its efforts-reflected in this report-form the analytical backbone of Portfolio 14 of the new JRC Work Programme 2025–2027, which is dedicated to enhancing societal resilience and our collective anticipation and preparedness for systemic risks.

This report demonstrates how better science can lead to and support better governance. It identifies common drivers of risk such as fragile governance, geopolitical tension and climate change-factors that undermine our ability to respond to emergencies and protect vital societal functions. It makes clear that resilience is not a sectoral issue—it is a shared responsibility that must be embedded across policy, economy, and society. The findings of this report have also informed the development of DG ECHO's Capacity Progress Report on the Response Capacities of the Union Civil Protection Mechanism, highlighting the importance of a comprehensive and coordinated approach to addressing capacity gaps in civil protection and disaster risk management.

As Commissioners for Research, Innovation and Startups, and for Equality, Preparedness and Crisis Management, we believe this report serves not only as a wake-up call-but as a roadmap. It calls on Member States, EU institutions, industry, and civil society to act together, to think systemically, and to prepare collectively.
Europe's strength lies in its unity and its capacity to act with foresight. We count on this report to inform our next steps toward an EU comprehensive risks and threats assessment.

Ekaterina Zaharieva
European Commissioner for Startups, Research and Innovation

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Abstract

This report presents an analysis of current and emerging risks in Europe, highlighting the need for a proactive and coordinated approach to risk anticipation, risk assessment and risk governance. In response to the increasingly complex and interconnected risk landscape, the European Commission and the High Representative have launched the EU Preparedness Union Strategy. This report aims to support the strategy's objectives by providing a scientific and evidence-based foundation for policy and operational decisions. It examines 47 risks and explores concepts such as cross-border risks, emerging risks, and High-Impact Low-Probability (HILP) events. The report's methodology involved a wide-ranging review of EU institutions' reports, scientific publications, and stakeholder consultations, and provides a multi-faceted perspective on Europe's risk environment. A EU-wide risk assessment framework is crucial; this report supports its development by fostering a shared understanding of different risks and methodologies to assess them, laying the groundwork for a more comprehensive and integrated multi-hazard risk assessment framework.

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Executive Summary

Europe faces an evolving and complex risk landscape marked by climate change, geopolitical instability, technological disruption, and risks that are transboundary, emerging and systemically interconnected. The European Commission's 'Analysis of Risks Europe is facing' report provides an analysis of 47 risks, originating from both natural and man-made hazards, that threaten lives, infrastructure, economies, and stability across the EU. To protect the vital societal function in the EU, a systemic, multi-hazard, and whole-of-society anticipatory risk governance is called for.

Policy Context

This report supports the first action of the EU Preparedness Union Strategy (JOIN (2025) 130 final), which calls for the development of an EU comprehensive risks and threats assessment. It is the prerequisite for a whole-of-society and, all-hazards approach to preparedness and resilience. It also contributes to broader European policy frameworks, including the Union Civil Protection Mechanism (UCPM) and its Union Disaster Resilience Goals, as well as the European Climate Adaptation Strategy. Together, these policies underscore the importance of foresight, integrated risk assessment, and cross-sector coordination to build a more resilient Union capable of handling cascading, cross-border, and systemic risks.

Key conclusions

A Fragmented but Rich Risk Landscape

The risk landscape in Europe is well documented, with extensive reporting by both EU institutions and the European Union Member States. The report identifies a fragmented landscape across risk definitions and classification, methodologies and standards. These heterogeneities pose challenges but also offer an opportunity. The richness and depth of sector-specific knowledge provide a solid foundation for designing a more comprehensive and coherent EU-wide risk assessment framework. Rather than seeking uniformity, the objective should be to promote interoperability—respecting the diversity of existing approaches while enabling shared analysis and collective action.

Systemic and Cascading Risks

Risks are increasingly interconnected and rarely occur in isolation; most arise from a complex interplay of multiple precipitating factors, including underlying risk drivers, other hazards, and the cascading impacts they generate. Climate change is causing more intense wildfires and longer wildfire seasons, which in turn may cause health hazards such as air pollution. Air pollution can lead to premature deaths, increased hospitalisations, and economic disruption due to reduced activity days. Conflict can disrupt essential services and supply chains and lead to sudden mass displacement of people, which may create overcrowded living conditions and strain healthcare services, increasing vulnerability to disease and resource scarcity. In the space domain, the uncontrolled growth of the satellite population, associated collision risks, and vulnerabilities in situational awareness are being exploited by malicious actors to conduct and conceal adversarial anti-satellite and other harmful activities.

A growing proportion of threats are systemic, meaning they interact across sectors and borders, causing widespread disruption. Scenario modelling and causal loop analysis show that anticipating these interactions can help build resilience and avoid compounding failures.

Different types of risks-natural, technological, or societal-often result in overlapping and cascading impacts. One of the most frequent consequences is economic disruption, which can ripple through supply chains, damage industries, create geopolitical tensions, and undermine livelihoods. This underscores the importance of boosting financial resilience and ensuring disaster-related risks are factored into economic planning. Similarly, threats like air pollution, pandemics, antimicrobial resistance, substance abuse, and food insecurity place enormous burdens on healthcare systems, highlighting the need for better prepared public health infrastructure and policies.

Climate change has significant implications for human mobility, influencing patterns and volume, and often interacting with other drivers such as conflict and economic conditions. Climate-related events, combined with armed conflict and weak governance, can drive population displacement, typically starting with internal or regional migration before potentially leading to international movement. This underscores the need for coordinated migration and disaster risk reduction policies.

Cyberattacks, extreme weather, and nuclear incidents can also disrupt essential services such as energy and transport, highlighting the need for robust, adaptable infrastructure. Because these disruptions cut across different risk categories, a cross-cutting whole-of-society and whole-of-government approach—focused on resilient economies, health systems, and infrastructure that support vital societal functions—offers the most efficient and scalable path to reducing impacts.

Evolving Impacts: Past and Future trends

The report presents an assessment on the losses associated with each risk over the last 10 years, and on the potential impacts for the next decade. The assessment shows a clear increasing trend, particularly for indirect impacts. Cyber threats, climate-driven weather extremes, hydrological and geophysical events, biological hazards, and technological disruptions all show a marked rise in both direct and indirect consequences. These impacts often stretch across sectors, affecting everything from critical infrastructure and health systems to economic stability and essential services. While some risks, such as environmental degradation, may stabilise in impacts, others—especially those linked to digital systems and geopolitical tensions—are set to escalate.

High-Impact, Low-Probability Events

Risks such as extreme solar storms, nuclear incidents, or pandemic outbreaks are rare but can carry severe consequences. The report calls for improved foresight tools, such as horizon scanning and scenario planning, to bring these events into regular risk planning cycles. Recognising and preparing for these risks is essential to avoid catastrophic failures in critical systems. Earth System Tipping Points pose further significant challenges. At least 5 of the 16 identified tipping points are at risk of crossing irreversible destabilising barriers at global mean temperatures above 1.5°C. Therefore, these tipping points can no longer be considered as low-likelihood event and require targeted risk assessment.

Common Risk Drivers

This study highlights several common key risk drivers closely linked to the 47 examined risks selected and prioritised by contributors as the most significant factors. Geopolitical instability is the most frequently associated factor, connected to nearly half of the hazards. Other major drivers include weak governance (19 hazards), climate change and urbanisation (each tied to 17), environmental degradation (14), and technological development (10). Climate change, in particular, is a consistent underlying factor across numerous risks, significantly influencing weather-related disasters such as droughts, wildfires, floods, and convective storms, as well as broader issues like food insecurity. Its effects are often compounded by environmental degradation. Societal vulnerabilities, such as poverty and inequality, or demographic developments were also highlighted by several contributors. Urban development, especially when poorly planned, also contributes to increased exposure to risks. Expanding infrastructure in hazard-prone zones increases the susceptibility of urban areas to threats such as earthquakes, air pollution, and Natech events (natural hazard-triggered technological incidents). The concentration of people and reliance on interconnected systems in cities make them particularly vulnerable to cascading crises—where one hazard may trigger multiple failures across several sectors.

Shared drivers like weak governance and geopolitical tension can amplify risks ranging from natural hazards to emerging digital threats, including cyberattacks, and disinformation. Strengthening institutional resilience, governance structures, technical standards, and cross-border cooperation can help contain or prevent several types of risks at once.

These above mentioned six risk drivers align with broader trends developed through foresight methodologies, particularly megatrends analysis. The JRC's Megatrends Hub monitors 14 megatrends, each with both short- and long-term shifts. Of these climate change and environmental decline, rapid technological advancement and connectivity, and the geopolitical rise of the East and South identified were identified as dominant themes. Megatrends include a set of sub-trends some linking with the risk drivers. Integrating these megatrends into planning enables better anticipation, management and sometime using sub-trends not yet developed helping to better understand complex and interconnected threats.

Gaps and needs identified

This report identifies gaps for each risk analysed, highlighting common gaps such as methodology limitations, data availability and accuracy, and insufficient scientific literature in research. Policy gaps include a lack of standardised guidelines where applicable, inadequate funding and resources, and insufficient international cooperation. Additionally, operational gaps exist, including inadequate data collection and monitoring, and challenges in implementing practices. Recommendations are provided for each risk, highlighting the need for infrastructure planning, policymakers' guidance and support, and clear plans to address gaps and secure investment, as seen in hydrogen fuel projects.

Related and future JRC work

This report builds on a series of precursor studies led by the JRC, particularly the recent Cross-Border and Emerging Risks in Europe report (Corbane et al., 2024), which provided a scientific analysis transboundary and emerging risks across the EU. That report, developed with contributions from over 60 experts across JRC Directorates, highlighted the growing interconnectedness and complexity of disaster risks in Europe, underscoring the need for coordinated approaches, open data, and cross-sectoral collaboration. It also served as a call to move from fragmented assessments to an integrated, anticipatory risk governance framework.

Looking ahead, the Joint Research Centre's 2025–2027 work programme will continue to advance the EU's capacity to anticipate and respond to systemic risks through the portfolio on Anticipation, Risks, and Resilience. This portfolio integrates research and innovation across societal resilience and systemic disruptive events, addressing both known and emerging threats as well as long-term future risks. It draws on past JRC efforts related to situational awareness, future risk foresight, and health crisis preparedness, while expanding them into a unified and transdisciplinary strategy.
In alignment with the European Commission's priorities the portfolio will support resilience-building across sectors—health, climate, energy, technology, finance, and more. It will use integrated foresight, behavioural insights, and knowledge management to inform policy and anticipate compound and cascading risks. The focus will be on developing tools and insights that bridge prevention, preparedness, response, and recovery, supporting coordinated EU-level action.

Building a Prepared Union

Given the interconnected and cascading nature of risks, the EU must adopt an all-hazards approach to preparedness. This means anticipating how different threats can interact and escalate across sectors. A whole-of-society approach is also essential—bringing together EU institutions, national and local authorities, industry, communities, and citizens. Effective risk mitigation depends on sharing data, resources, and expertise. Multi-hazard strategies, coordinated preparedness plans, and joint response mechanisms are key to building collective resilience, as recent crises have shown.

This report provides an initial step towards developing an EU comprehensive risks and threats assessment leveraging the findings of the JRC precursor studies on cross-border and emerging risks (Corbane et al. 2024), the Risks on the Horizon report of the JRC for foresight (Muench et al. 2024), and the Annual Strategic Foresight Report 2025 "Resilience 2.0" (EU 27). The JRC's contribution to the analysis of risks Europe is facing is part of an ongoing political process, aligning with the new Commission priorities on prevention and preparedness, particularly the Preparedness Union. The findings of this report have also informed the development of DG ECHO's Capacity Progress Report on the Response Capacities of the Union Civil Protection Mechanism. Regular updates to evidence-based risk analyses highlight the critical role of the JRC in shaping policy, reinforcing the link between scientific insights and policy initiatives.

1. Introduction

Amatrice, in the center of Italy, after the earthquake
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Europe is navigating an increasingly complex and interconnected risk landscape, where both known and emerging threats are converging to create significant challenges. The frequency and intensity of hazardous events such as floods, earthquakes, and storms, continue to pose a major risk, driven by climate change and other factors. Additionally, new and unpredictable threats, including hybrid attacks, are emerging, while global geopolitical tensions, technological disruptions, and societal vulnerabilities are exacerbating these risks. It is essential to address the persisting risks associated with natural hazards, which have the potential for major impacts and require proper management. At the same time, the converging risks and uncertainties underscore the urgent need for a new level of preparedness, rooted in a shared European vision of resilience, to mitigate the cross-sectoral and cross-border implications of these developments.

In response, the European Commission and the High Representative have launched the EU Preparedness Union Strategy[1] an ambitious and comprehensive initiative designed to strengthen Europe's ability to anticipate, prevent, and respond to emerging threats and crises. With its focus on a whole-of-government and whole-of-society approach, the strategy seeks to embed preparedness by design across all EU policies and actions. The Strategy's 30 priority actions aim to protect vital societal functions, enhance civil-military cooperation, foster population awareness, and develop a common EU-level framework for risk and threat assessments.

This report is grounded in that evolving context. It builds on the growing body of scientific and policy evidence developed over the past decade through key publications, including the Science for Disaster Risk Management book series, the European Climate Risk Assessment (EUCRA), and successive recommendations on integrated risk governance (v0, v1) and the more recent JRC report on Cross-Border and Emerging Risks. These documents have revealed persistent gaps in how risks are assessed and managed particularly regarding cross-border and systemic threats. They also point to the need for a more forward-looking, anticipatory approach to disaster and crisis management across Europe.

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The recent JRC report on Cross-Border and Emerging Risks collected contributions from more than 60 experts to analyse the current landscape of risks characterised by their potential for widespread impact across the continent, necessitating a coordinated European response. It underscored that while Europe has made significant progress in addressing cross-border risks, the increasing complexity of these threats calls for an even more coordinated and proactive approach. By leveraging science, improving cross-border cooperation, and investing in foresight, the EU can better anticipate and manage the risks of the future.

Recognising these gaps, the present report seeks to provide an integrated analysis of current and emerging risks in Europe. It offers a scientific and evidence-based foundation for policy and operational decisions and is intended as a stepping stone towards the broader goal of establishing a common EU framework for risk anticipation, in line with the objectives of the Preparedness Union Strategy.

The analysis covers a wide spectrum of risks; 47 in total from natural hazards to biological risks, armed conflicts, hybrid threats, and technological failure and Earth System Tipping Points. To support clarity and consistency, the report introduces and applies key concepts central to European risk governance. Cross-border risks are understood as threats that transcend national boundaries and require cooperative responses. Emerging risks refer to novel or intensifying hazards that are not yet

1 EU preparedness union strategy: Preparedness - *European Commission* (*https://commission.europa.eu/topics/preparedness_en*)

fully recognised or understood. High-Impact Low-Probability (HILP) events represent scenarios that are unlikely to occur but would have significant consequences if they did. These are examined within an all-hazards and all-of-society framework an approach that reflects the interconnected nature of today s crises and the need for inclusive, cross-sectoral resilience strategies.

This report's methodology involved a comprehensive review of 38 reports from EU institutions, Article 6 submissions under the Union Civil Protection Mechanism (UCPM), as well as relevant scientific publications and stakeholder consultations. To ensure a thorough understanding of Europe's risk environment, data and insights were gathered from institutional foresight exercises and policy documents, providing a multi-faceted perspective. The results are summarised in Chapter 2, which provides an in-depth examination of the key findings and their implications for policy.

In Chapter 3, the methodology used was designed to be collaborative, structured, and fit-for-purpose, aligning with the objectives of the Union Civil Protection Mechanism (UCPM) and the broader ambition of developing a harmonised, EU-wide risk assessment. Informed by a dedicated expert workshop held in September 2024, over 50 scientists from the JRC and colleagues from DG ECHO contributed to a targeted knowledge mapping exercise. Experts provided structured input on a broad range of risks, following a common template developed around the all-hazards and all-of-society approach. This input included assessments of past and future impacts, cascading effects, cross-border and emerging characteristics, and relevant adaptation and mitigation measures. While combining qualitative expert judgment with elements of semi-quantitative analysis, the methodology also acknowledges the limitations inherent in addressing both well-established and emerging risks within a short timeframe and a diverse evidence base. Challenges such as limited historical data for novel threats, fragmented terminology, and variable data quality were openly addressed.

As such, the report provides a foundational but non-exhaustive snapshot of key risks and their cross-sectoral impacts, and should be seen as a first step toward building a more consistent, anticipatory risk assessment framework at EU level. The selection and categorisation of risks in this report reflects our aim to cover as many risks as possible. However, the scope is necessarily limited by the in-house knowledge available at the JRC and the availability of external experts who have generously contributed their voluntary time to support this effort. The terminology used throughout the report is mainly based on the terms used in the Article 6 reporting guidelines[2], and the EU Overview of Risks[3]. The classification of the risks was done partly based on the UNDRR's hazard information profiles (HIPs)[4], (Murray et al., 2021). However, we acknowledge that some important risks may not be included in this selection. (e.g. financial related).

The report is structured to guide the reader from a broad overview of existing risk assessments and institutional reports to a detailed analysis of specific risks, before turning to risk interactions, scenario-building, and recommendations. It begins by mapping the risk knowledge base across the EU (Chapter 2), then provides a comparative risk analysis from scientific, governmental, and citizen perspectives (Chapter 3). Chapter 4 explores multi-hazard dynamics, cascading effects, and multi-hazard hotspots in Europe; and Chapter 5 concludes with actionable recommendations for strengthening European preparedness and resilience.

This work directly supports the goals of the Union Civil Protection Mechanism. It aligns with the renewed vision set out in the Niinistö Report and the EU Preparedness Union Strategy, both of which call for a more proactive and coordinated EU role in crisis anticipation and risk governance. By contributing to the development of an EU-wide risk and threat assessment, this report plays a key role in advancing preparedness as a shared European endeavour.

2 Reporting Guidelines on Disaster Risk Management, Art. 6(1)d of Decision No 1313/2013/EU *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC1220(01)*

3 EU Overview of Risks at the Knowledge Network *https://civil-protection-knowledge-network.europa.eu/eu-overview-risks*

4 Hazards Information Profiles (HIPS) *https://council.science/wp-content/uploads/2024/09/Hazard-Information-Profiles-HIPs-Flyer.pdf*

ing preparedness as a shared European endeavour.

Ultimately, the findings presented here mark an important step towards institutionalising foresight and anticipatory capacity within European risk governance. This includes addressing underexplored dimensions of systemic risk, such as the health impacts of climate change. Extreme heat events, air pollution, vector-borne diseases and climate-exacerbated disasters must be fully integrated into multi-hazard frameworks and risk governance strategies, as highlighted in the EU Adaptation Strategy and the European Climate and Health Observatory. They help lay the groundwork for a robust framework that can prevent future crises whether driven by natural, technological, or hybrid threats and enhance the resilience of European societies in the face of an increasingly uncertain future, highlighting the need for systemic thinking and integrated prevention strategies.

2. Overview of the overviews

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Copenhagen's unusually high benches are raising the alarm on climate change
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2.1. Diversity of risk reports

The European risk landscape has been extensively described over the past years through numerous reports and studies produced by various EU institutions. These efforts have been complemented by valuable contributions from Member States (MS), which regularly provide insights and data related to risks and disasters. This chapter will focus on the analysis of reports produced over the last 5 years. Their contribution also includes reports requested by different Commission services and EU regulations, such as those mandated by Article 6 of the UCPM Decision No 1313/2013/EU[5] on risk management activities.

The wealth of information compiled in these reports provides a nuanced picture of Europe's risk landscape, encompassing a broad range of topics, sectors, methodologies, and regional perspectives. However, the complexity and volume of these reports can hinder a clear understanding of the existing knowledge base, including research gaps, policy shortcomings, and operational challenges. These distinctions are important because they highlight the different types of actions needed to address the challenges. Operational gaps require improvements in implementation and practice, policy gaps require changes in laws and regulations, and research gaps require investments in knowledge and understanding.

To enhance the utility of this information, this section will synthesise key findings from EU institutions reports and those produced by Member States under various regulations, relating to disaster risk over the past five years. It will identify common themes, trends, and methodologies, highlighting areas of convergence and divergence and gaps, to provide actionable recommendations for improvement. This analysis aims to provide a deeper understanding of the current risk landscape and identify opportunities for enhanced risk management and prevention strategies.

2.2. Overview of risk assessment reports

2.2.1. EU Institutions reports

Mapping existing risk assessment reports entails a comprehensive collection and analysis of risk assessment reports prepared by various European institutions. This process aims to provide a holistic understanding of the existing reports, including the frequency of updates, the risk areas and risk clusters covered, the methodologies employed, and to identify common themes, trends, and patterns across different sectors, as well as the main conclusions drawn. The mapping exercise provides evidence on how to enhance the coordination and coherence of risk assessments across the EU.

The main steps adopted for this mapping and subsequent analysis are as follows:

a. Report Identification and Categorisation: Identify and gather reports from various EU institutions, such as the different Directorate Generals of the European Commission; European Parliament, Council of the European Union; European External Action Service (EEAS). Categorise the reports based on thematic areas (e.g., security and defence; disaster risk management (DRM); climate risk assessment and adaptation etc.).

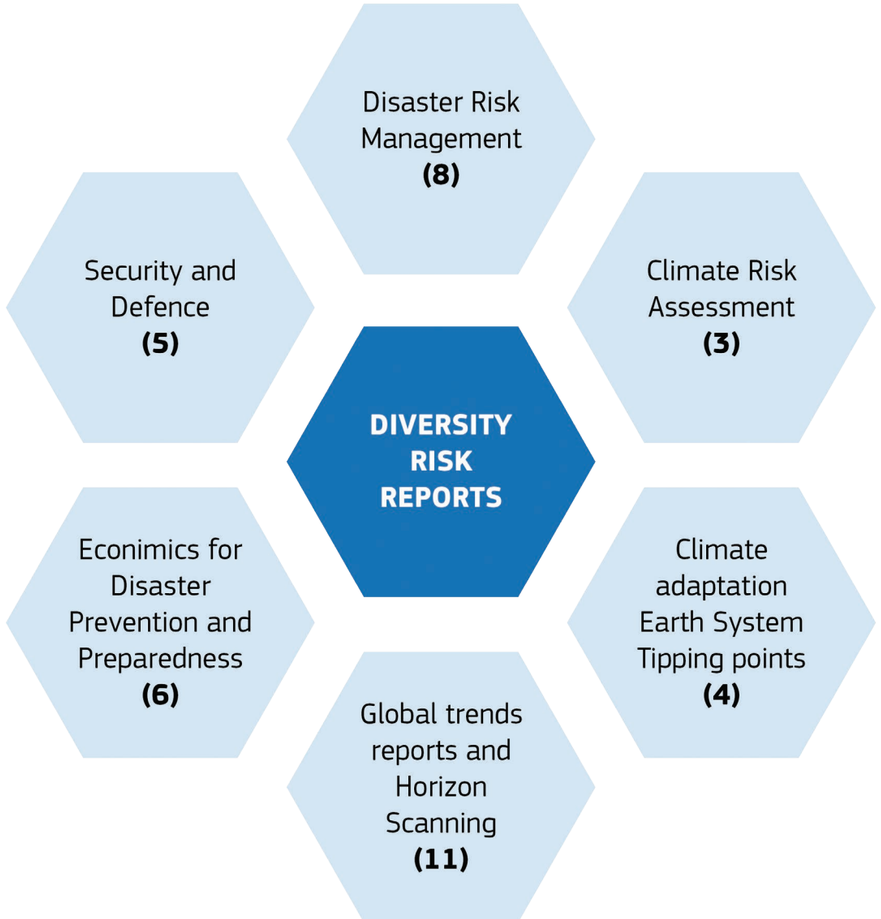
b. Report analysis, key findings and recommendations: Analyse the reports to extract information on the areas and sectors covered, the main aims and the methodologies used. This analysis will also distinguish whether the covers risk assessment and/or early warning systems, emergency preparedness, and/or post-disaster response and recovery. Furthermore, the analysis will also report on the potential gaps identified in the selected reports, covering research, policy, and operational aspects, which will in turn provide a foundation for a more in-depth analysis of gaps conducted by the expert authors for each risk category (section 3.1.8).

5 Art 6 UCPM 1313/2013/EU https://eur-lex.europa.eu/eli/dec/2013/1313/oj/eng

The reports produced by various EU institutions, analysed in this study primarily focus on key areas such as disaster risk management, security and defence, climate change and adaptation, economic strategies for disaster prevention and preparedness, as well as global trends and horizon scanning Figure 1. These areas of focus are further detailed in the following chapters and in Annex 1a, which provide a list of EU institutions' risk assessment reports published over the past five years. The analysis is made using a range of information for each report, including authorship, publication year, area and main topic, main objectives, methodology and approaches, main conclusions, and possible official contributions from Member States, as well as reporting frequency.

Building on this inventory, the following sections provide a categorised description of the main reports analysed, highlighting key findings, gaps, and areas for improvement.

Figure 1 Number of Reports analysed (grouped by thematic category)



Source: Authors' elaboration.

2.2.1.1. Disaster Risk Management reports

The reports in Table 1 are related to DRM and disaster risk reduction including national risk assessment and risk governance, climate change, cross-border and emerging risks.

Table 1 List of reports selected for the category Disaster Risk Management

Disaster Risk Management and Disaster Risk Reduction		
TITLE	**Authors**	**Year**
Natural disasters: anticipatory governance and disaster risk management from a local and regional perspective	European Committee of the Regions (CoR)	2024
The study aims to map and analyse tools to develop and improve the anticipatory governance approach to disasters, disaster risk management, and climate adaptation by Local and Regional Authorities (LRAs) across the EU.		
Mid-term Early Warning anticipating crisis 6 months ahead	JRC	2024
Advancing towards integrated mid-term early warning system that will aim at anticipating disasters and crises within a 6-month window. Ability to detect crisis a few months in advance that are likely to have major cross-sectorial impact is on high demand because it provides another opportunity for the transition from reactive to proactive crisis risk management strategies.		
JRC Cross-border and emerging risks 2024	JRC	2024
Analysis of complex disaster risks that transcend national borders and presents future challenges to the EU. Highlights the need to refine risk assessment methodologies and to address the co-occurrence of multiple hazards in a systemic multi-hazard framework.		
Strengthening the resilience of EU border regions	DG-REGIO	2024
Focuses on gap analysis of EU border regions identifying risks, vulnerabilities and gaps in crisis management tools and governance readiness and provides recommendations for improving data availability and quality.		
Evaluation Study of Definitions, **Gaps** and **Costs of Response Capacities for the Union Civil Protection Mechanism**	DG-ECHO	2024
Evidence on the appropriateness of the currently available response capacities. To support the European Commission to further develop disaster response capacities under the UCPM and to inform the creation of a dedicated EU-level response in specific.		
(Prevention Progress Report 2024) **on progress on implementation of article 6** of the Union Civil Protection Mechanism (Decision No 1313/2013/EU)	DG-ECHO	2024
Analysis of national reports on disaster risk management giving an overview of emerging, high impact and low probability risks and most important cross-border risks as identified by the UCPM Member and Participating States. Recommendations for actions needed to strengthen risk management. Regularly updated.		
Recommendations for **National Risk Assessment for Disaster Risk Management** in EU	JRC	2021
Guidelines and recommendations to support UCPM MS/PS on the implementation of Art. 6 reports.		
Overview of **natural and man-made disaster** risks the European Union may face	DG-ECHO	2020
Outlines potential disasters that the EU may face in the near future. A regularly updated publication report that draws on the findings of other reports and initiatives listed in this table.		
Science for Disaster Risk Management 2020	JRC	2020
Provides a comprehensive and actionable guide to DRM, with a focus on supporting all types of stakeholders in reducing disaster risk and promoting resilience.		

Source: Authors' elaboration.

EU Disaster Risk Management Needs and Gaps

The reports underline key operational gaps that include limited cross-border cooperation, inadequate data collection and sharing, and insufficient capacity and capabilities in some MS. Key needs include a whole-of-society approach, integrated policies, and improved research on risk assessment and complex risks, with a focus on prevention and preparedness.

Based on our JRC analysis of the selected reports, we conclude that to address existing gaps in this sector, the following areas require attention (**Table 2**):

Table 2 EU Disaster Risk Management Needs and Gaps identified from the selected reports

Research	Policy	Operational
• Need of solutions for improved data sharing among countries and harmonised risk assessment • Need of better understanding of emerging risks and intangible impacts (such as to cultural heritage and ecosystem services) • Need for systemic multi-hazard approach to manage simultaneous disasters (assessing risk drivers, compound relations and cascading impacts) • Need for improvement of disaster loss data collection and availability	• Limited mainstreaming of disaster risk management into other policies • Insufficient investment in risk prevention • Limited integration of climate change adaptation strategies in DRM planning • Need for a whole-of-society approach to DRM enganging public institutions, academic and research bodies, private sector, civil society, communities • Need to recognise and assess risk impacts of policy initiatives	• Need to enhance cross-border coordination among MS, including developing coordinated response efforts and sharing best practices and data • Need to establish a data sharing and information exchange mechanism between countries and stakeholders • MS have disparate levels of governance readiness and capabilities to address risks, with some countries having more advanced capabilities than others

Source: Authors' elaboration.

In the area of disaster risk management, the reports underline key operational gaps, including limited cross-border cooperation, inadequate data collection and sharing, and insufficient capacity and capabilities in some Member States.

2.2.1.2. Security and defence EU institutions reports

The analysis was limited to the reports listed in the Table 3 as it was focused on broader defence and security strategies and did not include more specific reports on topics such as cybersecurity, hybrid threats, counterterrorism, Permanent Structured Cooperation (PESCO) and border management, space related threats. This deliberate scope was chosen to maintain a comprehensive and holistic understanding of the EU's capacity to enhance citizens' security and defence. This list is not intended to be an exhaustive review of all available information.

Notably, the EU's security framework encompasses a wide range of areas, including migration, which

is often addressed as a separate policy domain. The analysis did not exhaustively review all available information (e.g. the European Security Union reports[6] are not analysed), but rather aimed to provide a general overview of the EU's defence and security strategies.

Regarding space-related threats, future analysis could usefully incorporate the EU Space Strategy for Security and Defence (EUSSSD)[7], the European Defence Industry Strategy (EUDIS)[8] and the Joint White Paper on Defence Readiness 2030[9], highlight the need to enhance EU readiness through a responsive and resilient European Defence Industry.

Table 3 List of the reports analysed in the category Defence and security

TITLE	Authors	Year
The Future of Conflict Early Warning: New Technologies and Policy Impact. Workshop proceedings	JRC	2025
The workshop held in Brussels on 19 March 2025 brought together experts and practitioners in conflict early warning to explore the challenges and opportunities of integrating new technologies, such as AI and Large Language Models, into policy-making. Discussions highlighted the potential of these technologies to enhance data collection and risk assessment while addressing practical challenges, including funding cuts, time constraints, and the lack of training, expertise, and limited trust in models among policymakers. JRC plans to summarise the outcomes of the discussions in workshop proceedings to be shared with all participants.		
Progress Report on the implementation of the Joint Communication - "**A New Outlook on the Climate and Security Nexus**"	Council of European Union, HIGH REPRESENTATIVE OF THE UNION FOR FOREIGN AFFAIRS AND SECURITY POLICY	2025
The Joint Communication is about addressing the impact of climate change and environmental degradation on peace, security, and defence, and proposes a new outlook on the climate and security nexus, aiming to strengthen climate and environment-informed planning, decision-making, and implementation in EU external action, and to support Member States in addressing the growing challenges involved.		
Safer Together - Strengthening Europe's **Civilian and Military Preparedness** and Readiness	Sauli Niinistö, former President of the Republic of Finland (special Adviser to the president of EC)	2024
Focused on enhancing the EU's preparedness and readiness to respond to future crises with 80 main recommendations for short, medium and long term.		
Strategic Compass 2024 for Security & Defence (Annual progress report) Strategic Compass 2022 for Security & Defence	EU (HR/VP for Foreign Affairs and Security Policy to the Council) EU (HR/VP for Foreign Affairs and Security Policy to the Council)	2024 2022
The reports above provide a framework for enhancing crisis management capabilities, including acting more swiftly and decisively, investing in defence capabilities, partnering more effectively with like-minded countries and organisations, securing resilience to emerging challenges.		
Migration Preparedness and Crisis Blueprint 2020[10]	EC	2020
Serves as a framework for managing migration-related crises to ensure a more coordinated use of existing legislation, developing an early warning and forecasting systems and supporting MS resilience for dealing with any type of migration crisis.		

Source: Authors' elaboration.

EU Security and Defence Needs and Gaps

The Niinistö Report and the Strategic Compass reports highlight the EU's need to take a more proactive stance in protecting its citizens, defending its interests, and projecting its values. This aligns with the EU Political Guidelines for 2024-2029 (Von der Leyen, 2024), which emphasise a comprehensive crisis management strategy driven by "preparedness by design."

Our JRC analysis of the selected reports reveals that the following areas need to be addressed to tackle existing gaps in this sector (**Table 4**):

Table 4 EU Security and Defence Needs and Gaps identified from the selected reports

Research	Policy	Operational
• Lack of understanding of the interactions between climate change, technology and security threats, hindering effective mitigation strategies • Limited research on the impact of emerging technologies (e.g. biotechnology, AI) on security and defence • Needs for innovative solutions and technologies to support security and defence	• Inadequate coordination and cooperation between EU MS and institutions • Unclear roles and responsibilities for implementing EU security and defence policies • Inadequate investment in security and defence capabilities	• Limited adoption of innovative solutions and technologies to support security and defence (e.g. scenario-driven approaches and "worst-case" scenario planning) • Insufficient public awareness and communication on security and defence issues • Inadequate preparedness to respond to major cross-sectoral crises

Source: Authors' elaboration.

For Security and Defence, the reports emphasise the EU's need to take a more proactive stance in protecting its citizens, defending its interests, and projecting its values, with a focus on comprehensive crisis management and strategic foresight.

2.2.1.3. Climate change and Earth system tipping points

In **Table 5** some of the EU institutions reports related to climate change and adaptation and recent policy brief dedicated to Earth System Tipping Points (ESTP).

6 European Security Union *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/promoting-our-european-way-life/european-security-union_en*

7 EUSSSD *https://www.eeas.europa.eu/eeas/eu-space-strategy-security-and-defence-0_en*

8 EUDIS *https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2024)762402*

9 Joint White Paper for European Defence Readiness 2030 *https://eda.europa.eu/news-and-events/news/2025/03/19/joint-white-paper-for-european-defence-readiness-2030*

10 This is a Commission Recommendation that sets up a network which generates specific reports

Table 5 List of the reports selected for the categories Climate Change, Climate Risk Assessment and climate adaptation

Climate Change, Climate Risk Assessment and climate adaptation		
TITLE	**Authors**	**Year**
One Health Governance in the EU	EC (RTD and the Group of Chief Scientific Advisors)	2024
The report considers how the EU can align with the initiative and incorporate key recommendations into its policies, improving coordination between different programs focusing on food production and agriculture, environmental policies, and policies for animal and human health.		
Earth System Tipping Points are a threat to Europe	JRC	2025
The summary highlights the current state of knowledge on Earth tipping points, including the potential risks and consequences of exceeding these thresholds, and the need for further research and investment in this area to better understand and mitigate these risks.		
European Climate Risk Assessment (**EUCRA**)	EEA, EC (DGs: CLIMA, JRC; and C3S)	2024
Identified 36 climate-related risks with potentially severe consequences across Europe and with cross-sectoral (energy, food security, ecosystems, infrastructure, water resources, financial stability, health) and cascading effects.		
Preparing society for climate risks in Europe - lessons and inspiration from **Climate-ADAPT** case studies	EEA	2024
Assessing the impacts of climate change and the effectiveness of existing adaptation measures in Europe.		
Responding to **climate change impacts** on human health in Europe: focus on floods, droughts and water quality	EEA	2024
Climate change adaptation and resilience in Europe, focusing on the impacts of climate change and the responses to these impacts at the national and EU levels.		
JRC **PESETA IV**	JRC	2023
The study aims to understand the effects of climate change on Europe and how these effects could be avoided with mitigation and adaptation policies.		
European State of the **Climate ESOTC**	ECMWF (C3S) , WMO	2023
Annual report drawing on previous year's climate conditions, trends, and extremes.		
Scaling nature-based solutions for **climate resilience** and nature restoration	EEA	2023
Concrete cases of nature-based solutions for climate adaptation and disaster risk reduction.		

Source: Authors' elaboration.

Based on the insights gained from our JRC analysis of the selected reports, we identify the following areas (see image below) as requiring attention to address existing gaps (**Table 6**). The identification of these gaps is crucial to develop effective strategies to mitigate and adapt to the impacts of climate change.

The gaps for addressing the ESTP s threats, on the other hand, will be addressed in a separate paragraph due to its novelty and specialty (**Table 7**). This topic requires a distinct approach, as it involves the identification of critical thresholds beyond which the Earth's systems may undergo abrupt and irreversible changes.

Climate Change in the EU: Needs and Gaps in Risk Assessment and Adaptation

Table 6 Needs and Gaps in Risk Assessment and Adaptation identified from the selected reports

Research	Policy	Operational
• Need for comprehensive data on the impacts of climate change on European societies and ecosystems are essential for informed policy-making and adaptation planning. • Insufficient evidence on the economic and social benefits of adaptation measures, which hinders the development of robust business cases and investment plans • Requirement for climate adaptation strategies that are specifically tailored to address the unique regional and local needs. • Research is needed to better understand the complex interactions between climate change and other socio-economic and environmental factors • Insufficient analysis of technical feasibility of risk measures required for climate change adaption projects to achieve acceptable risk	• Climate change adaptation needs to be more adequately integrated into existing policies and planning processes, including DRM. • Need for greater investment in preventive measures to avoid economic and social losses and to promote nature-based solutions. • Enhanced collaboration and participation among multiple stakeholders and sectors are required to develop and implement effective adaptation strategies. • Policies must account for the distinct needs and vulnerabilities of different regions and communities, ensuring that adaptation measures are equitable and effective. • Climate change adaptation requires a transdisciplinary approach, such as One Health Governance, to address interconnected human, animal, and environmental health challenges.	• There is a lack of coordination among stakeholders and insufficient public awareness of climate adaptation and risk assessment. • Inadequate funding is available for climate change adaptation, necessitating increased investment to support the implementation and scaling up of adaptation measures. • Improve the capacity of institutions and communities to effectively manage and implement adaptation measures is crucial. • Improve the exchange of knowledge and best practices across regions and sectors can enhance operational effectiveness in adaptation efforts. • Establishing robust monitoring and evaluation frameworks to assess the effectiveness of adaptation measures and make necessary adjustments.

Source: Authors' elaboration.

Table 7 Gaps and needs related with Earth System Tipping points identified from the selected reports

Research	Policy	Operational
• Methodological development is needed to Expand climate risk assessments into EU-level ESTP risk assessments by employing foresight approaches (e.g., storylines, scenarios, high-resolution digital twins) to address uncertainty. • Spatial-scale harmonisation is needed to align EU-regional assessments of ESTP risks, impacts, and vulnerabilities with national assessments, ensuring consistency across North, South, West, and East regions. • Determine the most relevant risk assessment outcomes to guide governance and policy action. is needed • Conduct comprehensive risk assessments that include knock-on effects, focusing on key governance clusters (e.g., food security, ecosystems, infrastructure) and incorporating One Health perspectives. • Develop methodologies to assess the economic impacts of ESTP and the financial risks associated with inaction, integrating biophysical and socioeconomic frameworks. • Enhance research efforts to better understand ESTP processes, dynamics, and reliable indicators of destabilisation, considering human, animal, and environmental health interactions.	• Develop strategies to prepare for the impacts of destabilised ESTP, focusing on risk assessments, resilience building, and adaptation planning tailored to ESTP that will directly impact Europe. • Assign risk ownership at the European level and ensure coordination with national-level risk assessments and responses, promoting a One Health approach. • Enhance EU cross-border and international cooperation to address ESTP risks and impacts, fostering collaboration across health and environmental sectors. • Support the development of harmonised guidelines for risk assessments and preparedness responses at both EU and national levels, integrating One Health principles.	• Compile and enhance existing early warning monitoring efforts and indicators, ensuring they are fit-for-purpose and incorporate One Health considerations. • Strengthen capacity to manage financial stability risks related to ESTP, considering the interconnectedness of human, animal, and environmental health. • Increase awareness of ESTP risks and improve communication to society and policymakers, highlighting the One Health dimension. • Establish periodic science communication on ESTP through ongoing channels like Copernicus services, ensuring information is accessible and relevant to diverse stakeholders.

Source: Authors' elaboration.

On climate related issues, the analysis identifies the need for attention in areas such as Earth System Tipping Points, climate risk assessment, and adaptation, with a focus on understanding and mitigating

the risks associated with exceeding critical thresholds of climate tipping point.
By addressing the gaps and needs identified in the One Health perspective report, the EU can better prepare for and respond to the complex challenges posed by Earth System Tipping Points, ensuring a more resilient and sustainable future for all (see in the report the section: European Climate and Health Observatory).

Building on a previous application of the One Health approach, the Commission launched the European Climate and Health Observatory in February 2021. The European Environment Agency (EEA) hosts this partnership between the EEA, the European Commission, the European Centre for Disease Prevention and Control (ECDC), the European Food Safety Authority (EFSA), and two other partner organisations (the Lancet Countdown in Europe, and the World Health Organisation Regional Office for Europe). This partnership provides policy and decision-makers with actionable knowledge on the past, current, and projected climate-related risks to human health at all life stages and in all settings, as well as on policies and actions.

2.2.1.4. Economics for disaster prevention and preparedness reports

Table 8 lists various reports on economics for disaster prevention and preparedness.
These reports aim to inform decision-making and investment opportunities in disaster risk management and climate adaptation in Europe. The documents cover topics such as smart investments, climate adaptation costs, disaster risk financing (DRF), and macro-fiscal impacts. They emphasise the need for a comprehensive approach, increased investment, and improvement in risk-informed budgeting, insurance, and data collection, while also calling for EU-level and national strategies to ensure financial preparedness for disasters.

Table 8 List of the reports selected for the category Economics for Disaster Prevention and Preparedness

Economics for Disaster Prevention and Preparedness		
TITLE	**Authors**	**Year**
Analytical indicators on physical risks	ECB	2025
Risk indicators that consider risks related to climate change-amplified natural hazards and assess how these affect firms ability to pay back loans and bonds and the performance of their equity. 9 areas covered: coastal flooding, river flooding, wildfires, landslides, subsidence, windstorms, water stress, droughts and rainfall variation.		
Climate Resilience Dialogue	17 organisations[11]	2024
The report aims to stimulate investment in good climate adaptation by: Identifying climate-related risks and their impact on people, businesses, and assets; Analysing the factors contributing to the climate protection gap; Proposing solutions to reduce, share, and transfer climate-related risks; Highlighting good practices and lessons learned from past climate-related events; Presenting integrated approaches to increase climate resilience and meet the needs of various stakeholders.		
Towards a European system for natural catastrophe risk management	EIOPA, ECB	2024

11 BIPAR European Federation of Insurance and Financial Intermediaries; Insurance Europ; World Bank; BEUC Bureau Européen des Consommateurs/The European Consumer Organisation; FERMA Federation of European Risk Management Associations; EIOPA European Insurance and Occupational Pensions Authority; UNEP FI United Nations Environment Programme Finance Initiative; EU-CoM EU-Covenant of Mayors; UNDRR; AAE Actuarial Association of Europe; SMEunited; UIPI Union Internationale de la Propriété Immobilière/International Union of Property Owners; PEIF Pan European Insurance Forum; EEA; CRO ForumChief Risk Officers Forum; RAB Reinsurance Advisory Board; AMICE Association des assureurs mutuels et coopératifs en Europe/ Association of Mutual Insurers and Insurance Cooperatives in Europe.

Proposes a possible EU-level solution to reduce the insurance protection gap for natural catastrophes by introducing a two-pillar system: 1. An EU public-private reinsurance scheme to increase insurance coverage for natural catastrophe risk, and 2. An EU fund for public disaster financing to support rebuilding public infrastructure after natural disasters.		
Report on the monitoring of climate-related risk to financial stability	DG FISMA	2024
Comprehensive analysis of the impact of climate change on financial stability in the European Union. It covers both transition and physical risks of climate change and finds that the impact on financial stability varies substantially between countries and economic sectors, pointing to potential systemic risks.		
Policy options to reduce the climate insurance protection gap	ECB, EIOPA	2023
The report discusses the growing concern of climate-related catastrophes in the EU and the need to address the widening insurance protection gap. It aims to solicit feedback on policy actions to tackle the climate insurance protection gap, including improving insurance policy design, developing public-private partnerships, and creating an EU-wide public scheme for natural disaster insurance.		
Climate change-related indicators	ECB	2023
The European Central Bank is developing climate indicators to: * Analyse climate risks; * Inform monetary policy; * Enhance transparency These indicators include sustainable finance, carbon emissions, and physical risks data		

Source: Authors' elaboration.

Our analysis of the selected reports highlights the need for attention in the following areas to address gaps in this sector (**Table 9**):

Economics for Disaster Prevention and Preparedness: Needs and Gaps in risk assessment

Table 9 Needs and gaps related to Economics for Disaster Prevention and Preparedness identified from the selected reports

Research	Policy	Operational
• Need for better information on projected impacts of climate risks (short, medium, long term) to financial stability, on insurance markets and to inform investements portfolios on sector/region	• Need for developing comprehensive national Disaster Risk Financing strategies among MS and for coordinated and effective policy measures at the national and EU level to address the climate insurance protection gap • Need to address the systemic risks associated with climate change, including the development of macroprudential policies and the integration of climate-related risks into microprudential frameworks	• The need for better coordination between public and private sectors, as well as more effective risk assessment and prevention • The need for more effective risk reduction measures, including enhanced emergency response and recovery efforts.

Source: Authors' elaboration.

In the realm of Economics for Disaster Prevention and Preparedness, the reports highlight the need for a comprehensive approach to disaster risk management, including smart investments, climate adaptation costs, disaster risk financing, and macro-fiscal impacts.

2.2.1.5. Global trends reports and horizon scanning

The reports selected for the category of Global Trends and Horizon Scanning, as listed in Table 10, cover a range of topics including global trends, crisis management, and strategic foresight, with a focus on interconnected areas such as climate change, cybersecurity, and geopolitical risks. These reports highlight the urgent need for holistic action to address the multitude of risks threatening global stability, economic growth, and human well-being. The risks, which can be broadly categorised into geopolitical, economic, environmental, technological, social, and (One) health-related areas, have the potential to significantly impact the world, underscoring the importance of proactive measures to mitigate their effects and seize emerging opportunities.

There are main consequences highlighted in the reports for each category[12]:

Geopolitical Risks:

- Rise of new global cartels controlling critical raw materials, disrupting supply chains and trade
- Escalating rivalries and antagonisms among great powers, leading to permanent global instability.

Economic Risks:

- China's economic decline due to structural issues, demographic decline, and real-estate collapse, impacting global trade.
- Rising global economic inequality leading to increased fragmentation and conflict within states.

Environmental Risks:

- Accelerating climate change, likely to exceed Paris Agreement targets (1.5 C-2 C).
- Rapid biodiversity loss, with over 500 species at risk of extinction by 2040.
- Increasing methane emissions, exacerbated by climate change.
- Environmental risks from increased mining of raw materials, especially in countries with lower environmental health and safety standards (China's mining operations in Africa and Asia that supply EU companies with lithium-ion batteries, European Court of Auditors - special report 15/2023.
- Creation of new environmental problems from alternative energies (e.g. in EU there is limited capacity for many years for recycling of lithium-ion batteries, European Court of Auditors - special report 15/2023).

Technological Risks:

- Misuse of AI by malign actors, threatening societal trust and democratic processes.
- Rising cybersecurity risk, including cybercrime and ransomware attacks, particularly targeting health services.
- Cyber and electromagnetic attacks, such as satellite hacking, Global Navigation Satellite System jamming, and spoofing, prominently target the space-enabled ecosystem, exploiting its vulnerabilities and posing significant risks to security and reliability (European Parliamentary Research Service, 2025).
- Chemical accident risk associated with hydrogen fuel and lithium-ion battery technologies

Social Risks

12 These categories have been identified through the analysis of the reports listed in Table 10 and are distinct from the risk categories selected for our analysis.

- Persistent economic inequality, with a growing wealth gap and 685 million people in extreme poverty. Social fragmentation, exacerbating other challenges and hindering response efforts.
- Farming out of externalities of climate change to countries outside the EU

Health-Related Risks[13]

- Potential for another pandemic (e.g. Disease X) due to urbanisation and climate change or the intersection of these with other drivers
- Climate change may amplify infectious disease emergence by altering vector habitats and stressing health systems.
- Antimicrobial resistance, a high-priority threat to health, potentially reducing global GDP by over 2%.

Table 10 List of reports selected for the category Global trends reports and Horizon Scanning

Global trends reports and Horizon Scanning		
TITLE	**Authors**	**Year**
JRC Horizon Scanning March 2024 New OPECS for minerals and other resources	EC (JRC)	2024
The need for critical raw material globally creates new alliances and impacts the supply chains. Some countries focus to secure access while others have the material resources to produce them. This creates a new form of alliances between the actors.		
Council ART Research Prospects for 2024 geopolitical situation	Council of EU	2024
In terms of crisis management, several key trends and potential flashpoints have been identified notably the Ukraine conflict, effects of climate change and enhancing climate resilience: Governments and organisations should take steps to enhance their climate resilience, including investing in renewable energy and implementing climate-smart infrastructure projects.		
Risks on the horizon	EC (JRC)	2024
Identifies 40 risks and 10 risk clusters. The study is unique in the sense that it does not start with a list of predefined risks. It uses signals from ESPAS Horizon scanning and through foresight workshops their future impact and development into risks is explored. Three risks are of existential nature: climate change, environmental degradation and loss of power by humans.		
ESPAS GLOBAL TRENDS REPORT 2024-2040 Choosing Europe's future	EC (JRC), EP, EESC, EEAS	2024
Identifies 10 global trends that can increase in impact until year 2040. Lists key uncertainties by year 2040.		
ESPAS Horizon Scanning	EC (JRC), EU (ESPAS)	2024
A network of human scanners within EU institutions collects each month around 100 emerging game changers that could have significant impact on society and policy. These are curated in workshops into weak signals, indicating possible new developments and facilitating the assessment and prioritisation for decision-making or for further examination and analysis.		
Future Shocks 2023, Anticipating and weathering the next storms	European Parliament (DGS: for External Policies of the Union, for Parliamentary Research Services and for the Presidency)	2023
Identifies several challenges and takeaways for EU, including the need for the EU to strengthen its resilience and preparedness in the face of various risks and challenges and the need for international cooperation and coordination to address global challenges, such as climate change and pandemics.		
Reference foresight scenarios: Scenarios on the global standing of the EU in 2040	EC (JRC), EU (ESPAS)	2023
Four foresight constructed scenarios describing the global standing of the EU by the year 2040. They can be used as a tool to stress test policy options.		
JRC Annual strategic foresight report: Towards a fair and sustainable Europe 2050: Social and economic choices in sustainability transitions	EC (JRC)	2023
Possible and necessary changes in the European social and economic systems as the European Union engages in managing sustainability transitions towards 2050. The study presents strategic areas of intervention covering a new social contract, governance for sustainability, people and economy, and the global perspective on sustainability.		
JRC Annual strategic foresight report: Towards a green & digital future	EC (JRC), EU (ESPAS)	2022
Emphasises the need for a twin transition, combining the green and digital transitions to achieve a climate-neutral, resource-efficient economy and society by 2050. The report highlights the importance of understanding the interactions between these two transitions, which are crucial for the EU's long-term objectives.		
Shaping and securing the EU's Open Strategic Autonomy by 2040 and beyond	EC (JRC), EU (ESPAS)	2021
The challenges and opportunities that the EU will face in the coming decades. The report identifies four key global trends that will impact the EU's capacity and freedom to act: climate change and environmental challenges, digital hyper connectivity and technological transformations, pressure on democratic models of governance and values, and shifts in the global order and population demography.		
JRC Annual strategic foresight report: Charting the course towards a more resilient Europe	EC (JRC)	2020
Explores the first structural lessons learnt from the COVID-19 crisis, and how foresight can help strengthen Europe's long-term resilience in an era of fundamental and rapid change. It analyses the EU s resilience across four dimensions: social and economic, geopolitical, green and digital.		

Source: Authors' elaboration.

Our JRC analysis of the selected reports reveals that the following areas need to be addressed to tackle existing gaps in this sector (**Table 11**):

13 https://www.dw.com/en/eu-faces-green-dilemma-in-sourcing-nickel-from-indonesia/a-69681557#:~:text=EU%20companies%20back%20off%20of,of%20an%20isolated%20Indigenous%20tribe

Table 11 Global Trends and Horizon Scanning: Identified Gaps and Needs from the Selected Reports

Research	Policy	Operational
• Need for research on a whole-of-society approach to tackle crises • Need for research on the impact of demographic changes, such as aging populations, on social cohesion and economic growth • Need for research on the impact of frontier technologies on society	• Need for a more integrated approach to address demographic risks, social cohesion, and economic growth • Need for better international cooperation to address global risks • Need for a more coherent all-hazard approach to risk management, including contingency plans, cybersecurity, and climate resilience	• Need to provide holistic approach and citizens dialogues methods in education and training programs.They should also be enhanced with foresight and anticipation modules. • Need for improved data, sharing collaboration (not only disaster data but also economical, geopolitical and horizon scanning signal information across different policy areas. • Need for shared scenario planning exercises to anticipate and prepare for potential risks • Need for new decision criteria to make risk decisions on climate adaptation projects • Need for a "preparedness dashboard" to monitor developments leading to risks.

Source: Authors' elaboration.

Global Trends and Horizon Scanning, the analysis reveals the urgent need for holistic action to address multiple risks threatening global stability, economic growth, and human well-being, including geopolitical, economic, environmental, technological, social, and (One) health-related risks.

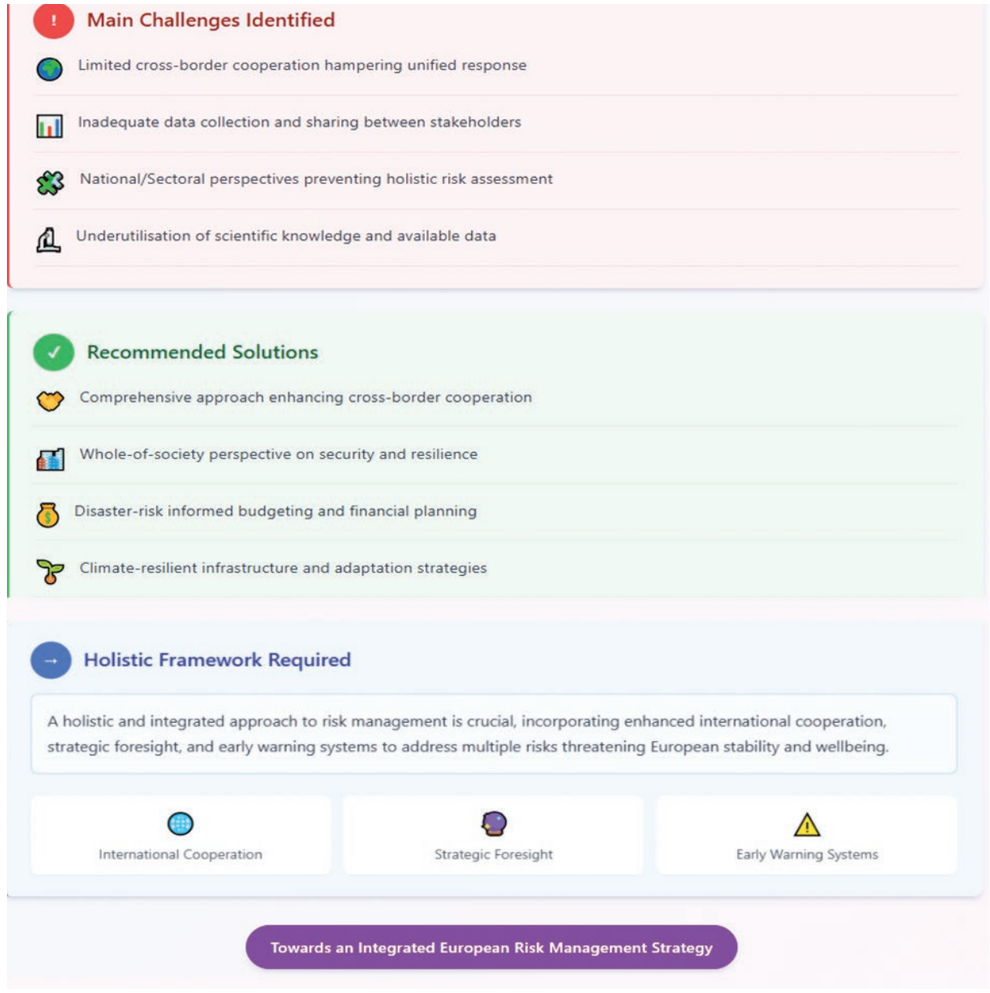
2.2.1.6. Key findings from EU reports analysis

The JRC study of the EU institutional reports selected highlights different key findings described below and resumed in Figure 2. The analysis indicates key operational gaps, including limited cross-border cooperation, inadequate data collection and sharing, and insufficient capacity and capabilities in some areas. Furthermore, efforts to detect risks and threats have been hindered by sectoral or national perspectives, making it challenging to anticipate potential cascading effects and cross-border implications. The underutilisation of scientific knowledge and data also poses a significant challenge.

To address these issues, a comprehensive approach is necessary, focusing on enhancing cross-border cooperation, improving data collection and sharing, and building capacity and capabilities in Member States. This approach should also encompass a whole-of-society perspective on security, investing in defence capabilities, and promoting macro-fiscal resilience through disaster-risk informed budgeting and financial planning.
Additionally, it is essential to prioritise understanding and mitigating risks associated with critical thresholds, climate risk assessment, and adaptation. Investing in smart investments, such as climate-resilient infrastructure, and conducting further research on Earth System Tipping Points can help address these challenges.

Ultimately, a holistic and integrated approach to risk management, incorporating enhanced international cooperation, strategic foresight, and early warning systems, is crucial to addressing the multiple risks threatening stability, growth, and wellbeing in Europe, including geopolitical, economic, environmental, technological, social, and (One) health-related risks. This approach will guide efforts on preparedness, leading to a more comprehensive understanding of risks and threats in Europe.

Figure 2 Resume of main conclusions identified by the EU reports selected



Source: Authors' elaboration.

3. Status of current and emerging risks in Europe

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This chapter presents an extensive analysis of a non-exhaustive list of **47 diverse range of risks that Europe is facing (Figure 3)**, encompassing risks from natural hazards such as floods, heatwaves, storms, droughts, wildfires, and earthquakes, as well as biological risks, armed conflicts, hybrid threats, and technological failures. The analysis explores the complex and interconnected nature of risks, such as cascading and/or compound relationships that include risks triggered by natural hazards, food insecurity, disruption of essential services, air pollution, terrorism, and the potential impact of emerging technologies such as artificial intelligence, cyber incidents in healthcare, and cybersecurity.

Furthermore, the chapter investigates implications of these risks, which are often of a cross-border nature, and their connection to various risk drivers, such as climate change, technological and/or geopolitical developments, highlighting the need for a comprehensive and coordinated approach to risk management. This is particularly relevant, as the Union Civil Protection Mechanism (UCPM) would most likely be mobilised in response to large-scale, transboundary crises with cascading impacts on health, infrastructure, or essential services.

To inform the UCPM prevention, preparedness and response, this chapter includes a foresight analysis, examining potential future risks and developments to enable anticipation and preparation for emerging challenges. The foresight perspective is crucial in identifying potential vulnerabilities and opportunities, allowing for the development of proactive strategies to address them.

The chapter also examines the potential risks linked to climate tipping points, which can have sudden and significant impacts on systems and processes. As defined by the Intergovernmental Panel on Climate Change (IPCC), a tipping point is a critical threshold beyond which a system reorganises, often abruptly and/or irreversibly. The concept of tipping elements, susceptible to tipping points, is also explored.
The scientific perspective presented in this chapter is also cross-compared with the national risk assessments undertaken by UCPM Member States/Participating States, prepared under Article 6 of the UCPM.

3.1. Scientific perspective of risks

This section summarises the JRC's analysis of 47 diverse risks that Europe is facing, with full details and references available in **Annex 2**, which serves as the primary source for the results presented here.

3.1.1. Methodology and limitations

The methodology for this chapter of the report was designed to ensure a comprehensive, collaborative and yet focused approach in support of UCPM Europe-wide risk assessment. In September 2024, we held a workshop, bringing together over 50 experts from various fields within the JRC, and colleges from DG ECHO. The scope of the work was outlined and consisted of creating a knowledge collection template to capture risk information from experts in the respective fields, in order to establish an initial knowledge mapping using an all-hazards and all-of-society approach[14], while ensuring relevance to the UCPM.

Figure 3 provides a visual representation of the risks assessed within each category. A detailed account of the experts' analyses can be found in **Annex 2**.

14 All hazards approach focuses on preparing for and responding to all types of hazards, rather than addressing them separately. All of society approach means engaging and involving all sectors, organisations and individuals. See EU preparedness strategy (*https://commission.europa.eu/topics/preparedness_en*).

The **classification of the risks** was done partly based on the UNDRR's hazard information profiles (HIPs), (Murray et al., 2021) with some modifications. In particular, we separated out **Cyber threats** into a category in itself instead of having it under Technological. Furthermore, we moved wildfires from Environmental to a category called Meteorological & Climatological and modified the category Societal from the HIPs to Geopolitical and Societal.

The "**Extra-terrestrial risks**" category covers space-related technological risks, including those affecting satellites, technological overdependence on space-based systems, and risks to space-related ground infrastructure. While these risks could be classified under general technological risks, their specific association with extra-terrestrial environments and phenomena informed our decision to include them within the extra-terrestrial risk category.
Disinformation is grouped together with cyber and hybrid threats, however disinformation can also be part of traditional media campaigns, Foreign Interference and Manipulation of Information (FIMI), and can be carried out as disinformation as a business.

For consistency and brevity, we will refer to '**Unexpected large-scale migration flow**' as 'Unexpected migration flow' in all figures and throughout this report.

Figure 3 Risk categories (bold) and risks analysed per each category[15]

Source: Authors' elaboration.

15 The classification of the risks was done partly based on the UNDRR's hazard information profiles (HIPs), (Murray et al., 2021) with some modifications (see the details in the section 3.1.1). For consistency and brevity, we will refer to 'Unexpected large-scale migration flow' as 'Unexpected migration flow' in all figures and throughout this report.

Scope and timeframe

The knowledge gathering process was conducted over a period of 3 months for each identified risk. This focused timeframe allowed for a rapid qualitative mapping of hazard and risk knowledge, which was designed to be aligned with certain aspects of the reporting guidelines under Article 6 of the UCPM[16]. It is important to keep in mind, that the contributors were requested to assessing only the specific aspects defined during the initial workshop, which ensured a consistent approach to the collection of information and analysis. Furthermore, the underlying goal of this knowledge collection is to develop a harmonised framework for hazard and risk information, which currently poses a challenge due to its diverse and fragmented nature. Risk assessment faces a significant challenge when dealing with emerging threats. Established risks, such as flooding, benefit from well-developed methodologies (Poljansek et al., 2021), leveraging historical loss data and probabilistic models that incorporate hazard layers, return periods, exposure, and water depth functions. This allows for comprehensive quantitative analysis. However, emerging risks like cybersecurity and hydrogen fuel adoption present unique difficulties. Their complex and evolving nature, coupled with limited historical data, makes it challenging to address all dimensions of risk hazard, exposure, vulnerability, and coping capacity in the same way. Consequently, these risks often require a more qualitative approach, focusing on scenario planning and expert judgment, rather than relying solely on traditional quantitative risk assessment methods. While this report encompasses both established and emerging risks, it acknowledges the inherent limitations of applying uniform assessment frameworks across such diverse risk categories.

Terminology and definitions

To maintain consistency of the knowledge gathered, the terminology used throughout the report is mainly based on the terms used in the Article 6 reporting guidelines6, and the EU Overview of Risks at the Knowledge Network[17]. This will facilitate cross-comparison and synergies between the information gathered from the JRC experts, and the information submitted by Member and Participating States of the UCPM every three years in their Article 6 summary reports (European Commission 2017, 2021, 2024).

In particular, some terms need additional clarification.

According to the Sendai framework for disaster risk reduction (UNDRR, 2017), **disaster risk** is the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. In the same framework, a **hazard** is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation (UNDRR, 2017).

Risks are labelled based on a key driver, or the sector they primarily impact. This practice relies on the assumption that such a label effectively captures the full spectrum of potential consequences, which can extend across various sectors. This naming convention, often shaped by institutional structures around focused research lines, may reinforce siloed expertise, hinder a comprehensive understanding of cross-sectoral risk impacts, and contribute to gaps in shared knowledge.

In this report, we are mainly using the term risk, since for a lot of the knowledge collected, past or potential future impacts on sectors is what we are aiming at assessing. However, there are occasions for which the term hazard is used, for example in cascading hazards, i.e. one hazard triggering another hazard (e.g. earthquake triggering a landslide).

According to the Sendai framework for disaster risk reduction (UNDRR, 2017), **risk drivers** or underlying risk drivers, are processes or conditions that influence the level of disaster risk by increasing levels of hazard, exposure and vulnerability or coping capacity. Disaster risk drivers are socio-economic factors, climate change, demographic change and/or technological developments.

According to risk concept there is a systematic approach to holistically address risk drivers. According to definition above, they are grouped into four dimensions: hazard, exposure, vulnerability and coping capacity. Different risks have different main drivers that we could act upon, even more in different phases of the DRM cycle. It needs to be pointed out here, that we only asked the contributors to provide us with a selection of drivers they considered most prominent. It is by no means an exhaustive list, or a thorough analysis of risk drivers.

Disaster impact is the total effect of a **hazardous event** or a **disaster** (UNDRR, 2017). The term includes economic, human and environmental impacts, and, for example, human health impacts may include fatalities, injuries, affected, disease, psychological effects and social well-being. In this report, we have asked the contributors to indicate levels of past impacts over the last 10 years, potential future impacts for the next 10 years, and potential cascading impacts[18], for their respective risks.

Note that the focus has been on negative impact, i.e. losses. However, an impact can also be positive, as exemplified by the potential impacts listed by the JRC experts on migration (**see unexpected large migration flow, under Geopolitical and societal in Annex 2**). What we are looking for is a number of most common impacts for the risks overview. Based on the contributions, we went on to group these impacts into categories, which are:

- Human health (e.g. fatalities, injuries, affected, disease)
- Displacement and migration (e.g. forced relocation, refugee crises, community displacement)
- Psychological and social well-being (e.g. stress, anxiety, social cohesion breakdown)
- Social and political Instability (e.g. social unrest, erosion of trust in institutions, political disruption)
- Economic disruption (e.g. business interruptions, financial losses and cost of re-build, restore and/or clean-up)
- Supply chain disruption (interruption of production, shortages)
- Environmental degradation (e.g. ecosystem damage, biodiversity loss)
- Essential services disruption (e.g. energy, water, healthcare, transportation, communication)
- Food and water security (e.g. agricultural losses, water scarcity, food shortages)
- Technological disruption (e.g. cyber incidents, AI risks related impacts, essential service interruptions)
- Cultural heritage Loss (e.g. damage to historical sites, loss of cultural practices)
- Education and skill development (e.g. disruption of educational systems, loss of workforce skills)
- Public health system (e.g. healthcare overload, delayed treatments, increased healthcare costs)
- Governance and institutional challenges (e.g. policy failures, institutional breakdown, corruption)
- Others

This list of impact categories, while not exhaustive, provides a snapshot of the insights shared by our contributors. It serves a dual purpose: it helps to identify the relative importance of impacts we aim to mitigate and the sectors we prioritize for protection in disaster resilience building while also highlighting current research priorities and areas requiring future focus. **By doing so, it provides an overview of the sectors and assets commonly affected by various hazards, ultimately informing**

16 COMMISSION NOTICE: Reporting Guidelines on Disaster Risk Management, Art. 6(1)d of Decision No 1313/2013/EU (2019/C 428/07)

17 EU Overview of Risks at the Knowledge Network https://civil-protection-knowledge-network.europa.eu/eu-overview-risks

18 Cascading impacts are those in which the impact of a physical event or the development of an initial technological or human failure generates a sequence of events in human subsystems that results in physical, social or economic disruption. Thus, an initial impact can trigger other phenomena that lead to consequences with significant magnitudes (Gill et al., 2022)

the broader purpose of this report.

Expert opinion and knowledge mapping

This chapter presents an approach taken in this report that is based on the collective expert opinion of JRC scientists. To synthesize this knowledge, we conducted an internal knowledge mapping exercise, combining qualitative information with the scientists' specialized expertise. It is important to understand that while this chapter offers a comprehensive overview of selected risk areas, it does not aim to provide an exhaustive analysis of all potential risks or every facet of the risks discussed. Rather, it represents a focused compilation of expert insights on specific, prioritized risk domains (more under scope and limitation) addressed by JRC experts.

Contributor Guidelines

Contributors were provided with a structured template to guide their assessments. They were asked to answer and provide knowledge on various field, which are listed below. For more detailed information about the criteria for the classifications and/or instructions on how to they were asked to fill the table, see sections 3.1.3 to 3.1.10 and Annex 2c.

These were the fields that the contributors were asked to respond to:

- Identify whether the risk has cross-border implications
- Determine if it qualifies as an emerging risk
- Assess whether the risk is high-impact, low-probability
- Indicate if climate scenarios are relevant in risk assessment
- Make a qualitative assessment of losses and damages over the past decade, distinguishing between direct and indirect losses, and economic and non-economic impacts
- Make a qualitative assessment of potential impacts over the next decade, distinguishing between direct and indirect losses, and economic and non-economic impacts
- Identify drivers of the risk
- Identifying cascading hazards and/or impacts associated with the risk
- Providing information on potential compound relationships
- Highlight gaps in risk management and relevant policy references
- Detail current and recommended adaptation and mitigation measures
- Indicate the level of uncertainty in assessing the risk

These guidelines were developed together with the experts at the workshop in September 2024. This is to be seen as a first step in gaining a more profound understanding of risks using an all-hazards and all-of-society approach.

Limitations

This report provides an overview of various risks, but it is essential to acknowledge its limitations as follows:

Risks covered in the report: The report covers a selection of risks, but it is not an exhaustive catalogue of all possible risks and their implications. The selection of risks and the topics to be addressed were determined through a collaborative process involving contributors and stakeholders and was partially based on the objectives of the UCPM and Article 6 reporting requirements.

The developed methodology: The methodology adopts a semi-quantitative approach, combining expert opinions, and knowledge mapping with quantitative elements building on the outcomes of detailed hazard-specific risk assessments. While the qualitative components provide rich, contextual information, the incorporation of quantitative data and analyses aims to introduce a level of objectivity and rigour. The results should be interpreted with caution, recognising the potential for bias and subjective interpretation.

Time constraints: The short timeframe for each risk assessment (2-3 months) allowed for rapid knowledge compilation but may limit the depth of long-term trend analysis or extensive data collection. To address this limitation, contributors were tasked with assessing only the specific aspects defined during the initial workshop, ensuring a targeted approach to data collection and analysis.

Data quality and availability: The report is based on available data, which may have gaps or inconsistencies. Contributors were tasked with identifying and addressing these gaps, and with providing recommendations for future data collection and analysis.

Geographic and thematic scope: The report focuses on a specific geographic and thematic scope, Europe and UCPM relevance which may not be representative of all regions or topics. The selection of the scope was determined through a collaborative process involving contributors and stakeholders and was based on the objectives of the UCPM and Article 6 reporting requirements.

By acknowledging these limitations, the report provides a transparent and comprehensive overview of the risks assessed, and highlights areas for future research and improvement

3.1.2 Risk characteristics analysed

This section outlines the definitions employed in our analysis to facilitate the comparison and characterisation of risks, ensuring a consistent and structured approach to understanding and evaluating the various risks examined. It provides the basis for the results reported in the following sections and also presents the outcomes of the comparative analysis, highlighting the key findings and insights derived from the comparison of the risks.

3.1.2.1. Cross Border Risks

Cross-border risks can have significant impacts on economic sectors, systems, borders, and regions. The expert contributors to this report were asked to specify if the risk that they have assessed is a cross-border risk, based on the definition from the UCPM Article 6 reporting guidelines[19].

> The identification of key risks with a potential cross-border impact and the estimation of their respective impacts might consider:
>
> i. Impacts resulting from risks generated in a neighbouring country or countries;
>
> ii. Impacts that spill over into a neighbouring country or countries;
>
> iii. Impacts affecting two or more countries simultaneously.

The explanations for cross-border risks provided in contributions can be summarised into three main categories:

Geographical spread and transboundary nature

Many risks are classified as cross-border due to their ability to spread across national boundaries.

19 Reporting Guidelines on Disaster Risk Management, Art. 6(1)d of Decision No 1313/2013/EU *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC1220(01)*

For instance, cyber threats, meteorological & climatological, and biological risks are noted for their capacity to affect multiple countries simultaneously or even have a global impact. Risk from natural hazards, like heatwaves, cold waves, and droughts can sweep through large areas, impacting neighbouring countries. Similarly, environmental hazards such as eutrophication and marine pollution (including pollution pollution by oil and chemicals, macro- and micro-litter) can easily spread in marine environments, affecting multiple coastal nations.

Interconnected systems and cascading impacts

Several risks are considered cross-border due to their potential to cause cascading effects across interconnected economic sectors, systems, and regions. For example, disruption of essential services can have far-reaching consequences that transcend national borders. The interconnected nature of supply chains and economic systems makes many industrial and technological risks inherently transboundary.

Shared resources and collaborative response

Some risks are classified as cross-border because they affect shared resources or require international cooperation for effective management. For instance, risks to shared water bodies like the Baltic Sea, or risks associated with nuclear and radiological materials, necessitate collaborative efforts across nations. Climate change-related risks, such as sea level rise and its impact on coastal hazards, are also considered cross-border due to their global nature and the need for coordinated international response.

These explanations highlight the complex and interconnected nature of many risks, emphasizing the importance of international cooperation and coordinated risk management strategies across borders.

3.1.2.2. Emerging risks

Emerging risks represent a complex and evolving category of risks that challenge traditional risk assessment and management approaches. For example, the increasing digitisation of health care has created new cybersecurity risks, while the emergence of novel pathogens and the adaptation of existing ones to human hosts constitute an evolving risk. These emerging risks require new approaches and strategies to assess and manage them effectively. Based on the definition from the UCPM Article 6 reporting guidelines[20], the expert contributors to this report were asked to specify if the risk that they have assessed is an emerging risk. Cross-border chemical incidents are another emerging risk that requires attention, as they can have significant impacts on human health and the environment. Effective response and mitigation strategies for such incidents must be based on a thorough understanding of the potential impacts and must involve cross-border collaboration and coordination.

20 Reporting Guidelines on Disaster Risk Management, Art. 6(1)d of Decision No 1313/2013/EU https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC1220(01)

Emerging risks are risks that may be:

- new risks;
- difficult to assess (with traditional risk assessment and management approaches) likelihood of harm;
- difficult to foresee, i.e. it is difficult to assess the probability that a certain consequence will occur at a specific time / place / condition;
- risks resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard;
- new or familiar risks that become apparent in new or under unfamiliar conditions.

Definitions of emerging risks also include the concept of newly created risks; newly identified/noticed risks; increasing risk, or risk becoming widely known or established.

Building upon the definition of emerging risks, we can identify several key domains where these risks are particularly prevalent and impactful:

Risks from meteorological & climatological and hydrological
Climate change is significantly altering the landscape of risks. Droughts, for instance, are now considered emerging risks due to their increasing frequency and intensity in Europe. These complex socio-natural events are becoming more difficult to assess and manage under changing climate conditions. Similarly, wildfires are classified as emerging risks, with their unpredictability heightened by climate change. Coastal hazards represent another critical area, where sea level rise acts as a risk multiplier. Events previously expected once in 100 years may occur every 1-10 years by 2050, posing unprecedented challenges to economies and ecosystems.

Technological and Cyber threats

Artificial Intelligence (AI) epitomises the complexity of emerging technological risks. The potential for misuse, unintended effects, or loss of control of highly capable AI models presents assessment challenges due to rapidly evolving capabilities. In the healthcare sector, increasing digitisation and the adoption of AI-enabled devices and Internet of things create new cybersecurity vulnerabilities. Natech (Natural Hazard Triggering Technological Disasters) risks are gaining recognition, with climate change expected to exacerbate these complex, inherently multi-hazard risks scenarios.

Furthermore, the space-enabled ecosystem is also becoming increasingly vulnerable to cyber and tech-driven threats, which have the potential to generate widespread effects on governmental and professional functions, large portions of the economy, and civil society, due to the challenges of attribution and the associated legal risks.

Biological risks

The emergence of novel pathogens and the adaptation of existing ones to human hosts represent significant biological risks. Recent events like the COVID-19 pandemic and the unprecedented spillover of highly pathogenic avian influenza H5N1 into cattle highlight the dynamic cross-species nature of biological risks associated to viral evolution. Several viral families remain of particular concern due to their zoonotic potential, high mutation rates, and capacity for sustained human transmission, such as Corono-, Orthomyxo-, and Filoviridae.

Antimicrobial resistance (AMR) is another critical emerging threat, recognised as one of the top global public health challenges. As AMR erodes treatment options, it necessitates integrated surveillance and One Health approaches, as well as innovative strategies to address the urgent need for novel countermeasures., Delsaux, P 2022.

Additional risks to be considered arise from biosafety and -security-related activities, such as the deliberate misuse of pathogens, laboratory accidents and dual-use research. These risks underscore the need for robust oversight, solid research practices and ethics, and internation cooperation to establish and uphold stringent standards.

Societal and Geopolitical Risks

The sudden large-scale arrival of migrants can put a strain on reception systems and border management capabilities, leading to new and unfamiliar challenges, as well as disinformation campaigns and attacks in the political and diplomatic domains. Hybrid threats, including cyberattacks on critical infrastructure and deliberate disruptions to energy supplies, pose evolving geopolitical risks that challenge traditional security paradigms. The increasing frequency and intensity of hybrid attacks against European democracies highlights the use of new tactics, tools, and alliances by adversaries. Moreover, the sophisticated combination of physical and non-physical hybrid attacks on critical assets, infrastructures, and services underscores the geopolitical nature of these risks, which raise significant security concerns due to their potential to unleash wide-ranging consequences and effects on civil society and the population.

3.1.2.3. High impact, low probability (HILP) risks

HILP risks are characterised by their extraordinary nature and potential for severe consequences that can overwhelm normal disaster response capabilities. These risks often require multinational responses and may trigger EU crisis mechanisms. HILP events are typically difficult to predict, with the potential for severe impacts, e.g. mass casualties, displacement, disruption of government functions across borders.

There is no universally agreed definition of what a high-impact, low probability risk is, an operational definition of such risks was adopted for the purpose of establishing the rescEU reserve capacities, since their aim is to help respond to extreme situations characterised by:

a. the unpredictability or extraordinary nature of a disaster;
b. the scale of the disaster, including mass casualties, mass fatalities, and mass displacement;
c. the protracted duration of a disaster;
d. the degree of complexity of a disaster;
e. the potential risk of severely disrupting the functioning of the national Government, including the provision of social, environmental, economic and public health services or the disruption of critical entities;
f. geographical range, including the potential for impacts to spread across borders;
g. other factors such as full activation of the Council's Integrated Political Crisis Response arrangements or citing the solidarity clause under Article 222 of the Treaty on the Functioning of the European Union that have a low probability of occurrence but a high potential impact, including risks that are characterised by their unpredictability, extraordinary nature, scale, protracted duration, complexity, and potential to disrupt critical entities.

Based on the contributions, it is clear that several risk categories may be classified as HILP, including cyber threats, some risks linked with artificial intelligence, which can be considered HILP due to their potential for large-scale impacts, and cyber incidents in healthcare. Other examples are risks from natural hazards, such as coastal floods and earthquakes, and biological risks like pathogens with epidemic concern, the latter is considered as HILP due to their infrequent but potentially devastating effects on public health, the economy, and international stability. These diverse and complex HILP risks, highlight the importance of adaptive risk management approaches in an increasingly interconnected world.

3.1.2.4. Climate-related risks

Climate change plays a crucial role in risk assessment across various sectors, highlighting the interconnected nature of climate change impacts on society. The expert contributors to this report were asked to specify whether the risk they assessed was climate change-related, and therefore, it is essential to consider the climate scenario in the risk assessment. While these links are explored, the cascading consequences of climate-related events on human health including mortality from heatwaves, vector-borne disease expansion, and pressure on healthcare infrastructure remain underdeveloped in current risk models. These health-related dimensions should be further assessed and incorporated into national and EU-level risk preparedness frameworks.

Risks related to climate change, including risks that are projected to increase in frequency, severity, or impact due to climate change. Risks for which climate scenarios are relevant in risk assessment.

Climate change related risks are prominent in several areas. Weather-related risks are significantly impacted by climate change, with projections indicating increased frequency and severity of heatwaves across the EU, particularly in southern European countries. Conversely, cold waves are expected to decline in intensity and frequency (Naumann G. et al. 2020). Climate change influences the frequency, intensity, and geography of convective storms, while warmer oceans lead to more intense tropical cyclones with greater cumulative damage. Droughts are projected to increase in frequency and severity in Europe, and climate projections are essential for assessing future flood risk as climate change is expected to lead to more frequent and intense flooding in Europe, particularly in coastal and low-lying areas, with a study by Alfieri et al. (2015) suggesting that the number of people exposed to flooding in Europe could increase by up to 50% by 2050 due to climate change.

Biological risks are increasingly intertwined with climate change, which accelerates the spread of infectious diseases and fuels rising bacterial infection rates, thereby facilitating the dissemination of pathogens and the emergence of antimicrobial resistance (AMR). The disruption of ecosystems and rising temperatures further elevates the risk of zoonotic spillovers. Climate change exacerbates pollution-related health risks by degrading air quality, altering pollutant dispersion patterns, and increasing the frequency and severity of climate-related natural disasters, which can compromise critical infrastructures and create cascading risks that amplify disease transmission.

Environmental risks, such as air and marine pollution, are intrinsically linked to climate change. Air pollutants act as short-lived climate forcers, and climate scenarios impact meteorology, which affects air quality. In marine environments, climate change can amplify eutrophication, marine pollution by oil and chemicals, and marine litter distribution (e.g. Climate change may influence changes in marine and air currents that can affect the spatial distribution of litter and other types of marine pollution and / or Hg levels in aquatic ecosystems, biota, and ultimately human exposures, although the magnitude and direction of the effects vary , Sonke et al. 2023)). Biodiversity loss is also identified as a climate-related concern.

Technological risks are significantly affected by climate change scenarios. Climate-related phenomena can cause disruption of essential services, and natural hazard trigger conditions must be considered in Natech risk analysis. Climate change scenarios are relevant for assessing risks associated with hydrogen fuel, ammonia production, renewable energy, and battery storage, particularly regarding extreme weather impacts on critical infrastructure.

Geopolitical and societal risks, including armed conflicts and food insecurity in Europe, are also influenced by climate change. However, this category of risks is significantly shaped by the rise in geopolitical confrontation, which is heavily reflected in the intensification of hybrid threats operations. These operations aim to weaken democratic societies by targeting their core foundations, decision-making processes, and techno-economic structures. While the impact of climate change on

conflict risk appears relatively small compared to other factors, it is projected to negatively affect European food production and exacerbate health and social inequalities. Moreover, the experience of conflicts in Syria, South Sudan, and other places suggests that climate change can play a significant role in exacerbating tensions and instability, and it is likely that its influence will grow in the future.

Climate change also has significant implications for human migration, influencing both the patterns and volume of migration, although the relationship is complex and context-dependent, often interacting with other drivers such as conflict and economic conditions, and typically resulting in initial internal or regional migration before potentially leading to international movement.

3.1.2.5. Risks classified as cross-border, emerging, climate change-related, and HILP

The vast majority of risks identified in this report are considered cross-border, as they have the potential to impact multiple countries or regions simultaneously. This is due to the increasingly interconnected nature of the systems worldwide, where global supply chains, international travel, and digital communication networks can facilitate the rapid spread of risks across borders. For example, disruptions in global supply chains due to natural disasters or geopolitical tensions can lead to widespread economic and social impacts, affecting availability and prices of goods across continents. For instance, a cyber-attack on a critical infrastructure in one country can have ripple effects on the global economy, while a pandemic can spread rapidly across the world through international travel. Similarly, climate-related risks such as rising sea levels, droughts, and extreme weather events can affect multiple countries and regions, highlighting the need for international cooperation and coordination to mitigate and manage these risks. This underscores the importance of multilateral agreements and collaborative frameworks to effectively address and manage cross-border risks.

Furthermore, many risks are emerging, meaning they are new or evolving, and their potential impacts are not yet fully understood. These include risks associated with technological advancements, such as artificial intelligence and biotechnology, which present both opportunities and challenges that require adaptive regulatory frameworks. Climate change-related risks are also a significant concern, as they are driven by climate change and can have far-reaching consequences for the environment, human health, and the economy. The increased frequency and severity of extreme weather events necessitate robust adaptation and mitigation strategies to protect vulnerable individuals, populations and infrastructure. Finally, some risks are classified as High-Impact, Low-Probability, which are characterised by their potential to cause significant damage or disruption, despite their relatively low likelihood of occurrence. Examples include catastrophic events such as large-scale natural disasters or unprecedented technological failures, which require comprehensive risk assessment and emergency preparedness planning.

Figure 4 presents the list of risks that are classified as cross-border, emerging, climate change -related, or HILP, as assessed by JRC experts. It is important to point out that some have identified the risks as HILP, despite seemingly having a relatively high frequency of occurrence. **Floods** is an example of this, however, the reasoning is that the actual likelihood in many locations is very low, and when an event does occur, the consequences can be catastrophic. The loss of biodiversity is another example, where the risk is classified as HILP due to a certain degree of uncertainty as regards to timing, location and triggers. **Hybrid threats** demonstrate mixed risk characteristics across all domains. They can manifest as cross-border risks, though some impacts may remain confined to domestic contexts. These threats are partially emerging, combining established and/or evolving threats. Their relation to climate risks is context-dependent, as certain scenarios may intersect, while others remain unrelated. Similarly, their classification as high-impact, low-probability risks varies, and there are both threats that are considered HILP, and others that are not.

Figure 4 Characterisation of risks by JRC experts. The red dots mean yes, and the blue dots mean no

RISK CATEGORIES	RISK	Cross-border	Emerging	Climate scenario	HILP
Cyber threats	Artificial Intelligence	●	●	●	●
	Cyber incidents in healthcare	●	●	●	●
	Cybersecurity	●	●	●	●
	Disinformation	●	●	●	●
Meterological & Climatological	Heatwave	●	●	●	●
	Cold wave	●	●	●	●
	Convective storm	●	●	●	●
	Tropical cyclone	●	●	●	●
	Drought	●	●	●	●
	Wildfires	●	●	●	●
Hydrological	Floods	●	●	●	●
	Coastal Floods	●	●	●	●
Geophysical	Earthquake	●	●	●	●
	Tsunami	●	●	●	●
	Volcanoes	●	●	●	●
Biological	Pathogens (epidemic concern)	●	●	●	●
	Antimicrobial Resistance (AMR)	●	●	●	●
	Pollution-Driven Non-Communicable Diseases Adverse Health Effects	●	●	●	●
	Illicit Drug Abuse, Trafficking, and Public Health	●	●	●	●
Environmental	Air pollution	●	●	●	●
	Eutrophication	●	●	●	●
	Marine pollution by oil & chemicals	●	●	●	●
	Marine macrolitter	●	●	●	●
	Marine microlitter	●	●	●	●
	Biodiveristy loss	●	●	●	●
Technological	Nuclear/Radiological	●	●	●	●
	Disruption of essential services	●	●	●	●
	Natech	●	●	●	●
	Hydrogen fuel risks	●	●	●	●
	Ammonia for Hydrogen Fuel Production and Transport	●	●	●	●
	Renewable Energy material sourcing and processing	●	●	●	●
	Battery energy including storage	●	●	●	●
	Carbon Capture Storage and Distribution	●	●	●	●
Geopolitical and societal	Armed conflicts	●	●	●	●
	Hybrid threats	●	●	●	●
	Illicit trafficking of nuclear/radiological material	●	●	●	●
	Terrorism	●	●	●	●
	Food insecurity in Europe	●	●	●	●
	Unexpected Migration Flow	●	●	●	●
Extra-terrestrial	Damage from solar storms	●	●	●	●
	Major meteorite impact	●	●	●	●
	Space debris	●	●	●	●
	Kessler syndrome	●	●	●	●
	Uncontrolled reentry or launch	●	●	●	●
	Attacks on satellites	●	●	●	●
	Attacks on space-related ground infra	●	●	●	●
	Technological over-dependence	●	●	●	●

Source: Authors' elaboration.

3.1.3. Integrating foresight into DRM

To complement the expert analysis, we also integrate foresight methods to provide insights on developments that are not directly linked with a risk but can affect drivers leading to risks in the more longer term (beyond 10 years). Foresight provides an alternative way to look at possible futures. It differs from forecasting by its more qualitative approach and by exploring holistically the future by making scenarios or horizon scanning with the aim to find new not yet existing developments. This approach allows for the identification of emerging technologies and social dynamics that could transform risk landscapes, providing a proactive rather than reactive attitude in DRM.

DRM can be enhanced with foresight by expanding the time horizon to also include early-warning based foresight. Looking longer term can strengthen preparedness for future threats by exploring vulnerabilities and possible new developments affecting key drives linked with risks. Incorporating foresight into DRM enables the anticipation of systemic risks, such as those arising from interconnected economic, social, environmental, and health systems, which are often overlooked in traditional risk assessments. By adopting a transdisciplinary approach, foresight allows for a more holistic understanding of risks, considering the complex interplay between human, animal, and environmental health as emphasized in the One Health framework. This integration is crucial for identifying vulnerabilities that span across sectors and disciplines, such as the emergence of zoonotic diseases linked to climate change and habitat disruption, or the cascading effects of economic instability on food security and public health. Because risks can be complex in terms what is creating them and the areas that they affect, foresight provides tools that DRM can use to assess this.

The term foresight, sometimes used interchangeably with anticipation, is used here to refer to a time horizon that extends beyond short- and medium-term outlooks. Traditionally in DRM the term foresight is normally used to anticipate what can happen the coming 6 months for example. **Foresight typically examines time horizons of 10 years or more, which allows the foresight process to be less reliant on current events and enables a more straightforward exploration of alternative futures**. This long-term perspective is crucial for identifying and planning for "wild card" events, which are low-probability but high-impact scenarios that could significantly alter the risk landscape. Trying to have a more long-term look enables also to explore more widely how different trends might evolve and how different approaches can steer their direction. It is also more qualitative than quantitative and relies much on the opinion of foresight workshop participants.

Looking more long term allows us to explore potential high-impact, low-probability events that can affect society, such as a financial crisis and its consequences on geopolitics and disaster risk management. While some events may be unforeseen (so-called "**black swans**"), many disasters can be anticipated and mitigated if warning signs are heeded. For example, the 2008 financial crisis was preceded by warning signs that were ignored. By taking a proactive approach to risk, we can work to prevent or minimize the impact of potential disasters, Greenwood et al. 2022.

Several of the tools in foresight are relevant for DRM. One tool is megatrends, which are a collection of trends that are already observable today, but which have the potential to have a disruptive change in the future. The megatrends cover broad range of different developments ranging from migration to change in consumer behaviour. Moreover, integrating megatrends into DRM planning can help align strategies with broader societal shifts, ensuring that responses are adaptable to future changes. Looking at these at first sight unrelated to risk aspect, but their impact on drivers leading to risks can give insights not usually included in risk assessments.

Several foresight studies have looked at resilience or open strategic autonomy by year 2040. These have been explored using **megatrends, horizon scanning or foresight scenarios** of the future. A

recent tool relevant for DRM is "**Polycrisis exploration workshop tool**"[21]. All the tools are available at JRC homepage. Foresight tools like these facilitate the exploration of complex, interrelated crises, allowing stakeholders to develop more robust, flexible and transdisciplinary strategies for managing future risks and 21st century societal needs in emerging new threats of diverse origin (OECD, 2020).

Environmental degradation is identified in many foresight studies as a risk above all. The ESPAS Future shocks identifies that not solving it, other risks will become of secondary importance Addressing environmental degradation and one health emerging threats is essential not only for mitigating ecological risks but also for enhancing societal resilience to other risks that stem from environmental and societal decline. Moreover, (One) health threats and demographic changes are not only significant megatrends, but also pose substantial risks, highlighting the complex interplay between these factors and the need for a comprehensive approach to mitigate their impacts. This is a subject that can be addressed with foresight tools. By integrating (One) health and demographic trends into foresight processes, DRM can better prepare for shifts in population dynamics and public health challenges that may arise over the long term.

3.1.4. JRC expert analysis of past losses and potential future impacts

Disasters can cause significant losses and damages to infrastructure, economy, and human life. Understanding the extent of these losses and damages is crucial in developing effective disaster risk management strategies. Chemical incidents, for instance, can result in significant economic losses, as well as long-term health effects on the environment and on health for individuals and communities. The potential impacts of such incidents can be mitigated through effective preparedness and response measures, including the use of exposure assessment and risk assessment tools.

Data and statistics are important in understanding the impacts and costs of disasters. Systematic data collection and analysis can be used to inform policy decisions to help reduce disaster risks and build resilience. Disaster loss databases allow disaster risk managers to explore patterns and trends in disaster risk on the basis of past events. Understanding these patterns and trends can help in anticipating future losses from extensive events (frequent events) and in understanding whether disaster risk management is effective in reducing this kind of risk.

The process of risk assessment involves three key stages: risk identification, risk analysis, and risk evaluation (Poljansek et al., 2021). The outcomes of this process inform decision-makers on how to manage the risk, feeding into disaster risk management planning and the implementation of prevention and preparedness measures. Additionally, understanding the potential evolution of impacts over time can facilitate comparability of risks, and support the preparation of the UCPM's response, public authorities and private companies and mitigation strategy.

In essence, the use of data and statistics, combined with risk assessment, enables disaster risk managers to make informed decisions about how to mitigate the effects of disasters. By analysing past events and anticipating future losses, decision-makers can develop effective strategies to reduce the likelihood and impact of disasters, ultimately minimising loss and damage and promoting sustainable development (EC, 2019; JRC, 2019).

In this section, JRC data and summary statistics on past losses and damages are reported for each risk analysed, alongside the potential future impact of disasters. The timeline analysis spans a 10-year period, looking both backward and forward, providing a comprehensive view of past trends and future impacts projections.
The losses and potential impacts analysed include direct and indirect effects (Prevention Web, 2015)[22].

21 Polycrisis exploration workshop: Workshop tool to facilitate strategic conversations about current and future risks, disasters, and polycrisis. *https://knowledge4policy.ec.europa.eu/polycrisis-toolkit_en*

22 Direct and indirect losses (Prevention Web, UNDRR 2015) https://www.preventionweb.net/understanding-disaster-risk/key-concepts/direct-indirect-losses

The first category refers to the immediate physical or structural impact caused by the disaster, such as the failure of infrastructure and/or casualties caused by the force of high winds, flooding, or ground shaking. The indirect effects are the subsequent or secondary results of the initial disruption, such as business interruption losses. Furthermore, when possible, the analysis also separated between economic and non-economic losses or potential impacts. For example, human losses are considered non-economic, whereas damages to infrastructure are economic.

Potential losses over the next 10 years have been assessed by experts. It is important to note the limitations of this assessment, as experts were asked to indicate whether potential impacts are expected to be low, medium, or high. These categories are based mainly on qualitative expert judgement, since reliable long-term loss data and standardised methodologies are often lacking. The classifications reflect a blend of expert opinion and, where available, supporting data.

For example:

- Low: Direct impacts from AI are considered low. While AI itself is not expected to cause significant direct losses, its unintended or malicious use could enable other risks, such as cyber incidents or disruptions to critical infrastructure.
- Medium: Marine chemical pollution is rated as medium. Direct infrastructure damage is usually minimal, but economic losses from chemical spills can be significant, and environmental impacts can range from minor to severe depending on the situation.
- High: Major events like pandemics or large earthquakes are classified as high. These can cause widespread societal and economic disruption, with examples including the COVID-19 pandemic and megathrust earthquakes, both of which have resulted in severe global consequences.

Some assessments include the likelihood of events, while others focus solely on the impact if the event occurs. For instance, a major meteorite impact would have extremely high consequences, but its low probability alters the overall risk assessment. In summary, these risk classifications are informed estimates, reflecting both the potential severity and the uncertainty due to limited data and evolving risk landscapes.

In this analysis, the following risks are excluded: **Hybrid threats** and **unexpected large- scale migration flows**. These risks were omitted due to their complex and multifaceted nature, which poses significant challenges in terms of understanding, quantification, and prediction, making it difficult to accurately assess and report on their potential impact. Both risks are considered emerging, and their likelihood and potential consequences are expected to increase in the future, making them a growing concern. Additionally, the analysis of potential impacts related to terrorism was not reported, as it is challenging to predict whether the threat will escalate or diminish in the future. Nevertheless, it is likely that new emerging threats and modus operandi could emerge, for which we may not be adequately prepared.

Figure 5 represents the total (direct and indirect) past losses (in blue) and potential total impacts (in orange) for each risk analysed. Risks marked with an asterisk (*) are considered emerging risks, and their emergence is likely to increase the potential future impacts. **Figure 6** and **Figure 7** represent, respectively, the direct past losses and potential impacts, and indirect past losses and potential impacts. Pursuant to the analysis based on the author s contributions and the details are in the Annex 2, the main results by risk category are evidenced as follows:

Cyber Threats

Artificial Intelligence, cyber incidents in healthcare, and cybersecurity exhibit a notable increase in potential impacts compared to past losses.

Regarding AI related risks, the historical data on past losses are limited, with few confirmed incidents or events where a high economic or non-economic impact can be directly and primarily attributed to

AI. However, the rapid advancement and deployment of AI technologies have raised concerns among researchers and policymakers about potential future risks. While direct future impact may be low, unintended effects of the use of AI, or its malicious use, can lead to subsequent impacts (indirect). Therefore, the indirect potential impact in absence of the necessary mitigations can be high, as AI can play a role in the materialisation of systemic risks, such as in relation to major accidents or disruptions of critical sectors and infrastructure, or in relation to major cyber incidents, with potentially high economic impact. AI's role in cybersecurity is particularly noteworthy, as it can both mitigate and exacerbate risks. On one hand, AI can enhance threat detection and response capabilities; on the other hand, it can be exploited to launch sophisticated cyber-attacks that are difficult to detect and counter. Similarly, AI and large language models can play a role in risks impacting individuals and societies, e.g. through intentional misuse or unintended issues resulting in public health and safety crises, negatively affecting democratic processes, or potentially lowering entry barriers that lead to increased biological or nuclear risks, including their accidental or intentional release, up to the point of the creation of weapons. Moreover, AI systems can perpetuate or even exacerbate existing biases and inequalities, leading to unfair outcomes in areas such as hiring, law enforcement, and lending. This can have significant societal implications, eroding trust in institutions and exacerbating social divides. Additionally, the deployment of AI in surveillance and data collection can lead to privacy violations and increased state surveillance, raising ethical and human rights concerns. The integration of AI in autonomous systems, such as self-driving vehicles and drones, presents unique challenges. While these technologies promise efficiency and safety improvements, they also pose risks related to system failures and liability issues in the event of accidents. Furthermore, the potential use of AI in military applications raises concerns about autonomous weapons systems and the ethical implications of delegating life-and-death decisions to machines. Recent literature also highlights the environmental impact of AI, as the computational power required for training large AI models can lead to significant energy consumption and carbon emissions. This underscores the need for sustainable AI development practices and the consideration of environmental impacts in the deployment of AI technologies. In summary, while AI holds great potential to drive innovation and efficiency, its development and deployment must be accompanied by careful consideration of ethical, societal, and environmental risks. Policymakers and researchers are urged to develop robust frameworks for AI governance, focusing on transparency, accountability, and the mitigation of both direct and indirect risks. This includes fostering interdisciplinary and transdisciplinary collaboration to ensure that AI technologies are aligned with broader societal goals and values.

Meteorological & climatological Risks

The impacts of most climate-related hazards, including heatwaves, convective storms, tropical cyclones, droughts, and wildfires, are escalating due to climate change-driven factors such as rising temperatures and altered precipitation patterns, which are being exacerbated by human activities. In contrast, as the planet warms, the likelihood and severity of cold snaps are reducing, primarily due to increased mean winter temperatures. Although demographic shifts, such as population ageing, may increase vulnerability to cold temperatures, the overall warming trend is expected to lead to fewer cold-related events. Nevertheless, it is essential to acknowledge that the residual impacts of cold waves on vulnerable populations, including the elderly and homeless, may remain significant due to demographic factors.

Hydrological risks

Floods and coastal floods are experiencing increased impacts due to climate change, driven by factors like rising temperatures, sea level rise, and human activities. This trend is expected to persist, presenting substantial economic, social, and environmental risks that will require proactive mitigation and adaptation strategies.

Geophysical Risks
The impact of earthquakes, tsunami and volcanoes is expected to remain significant in certain EU countries, while being moderate or low in other areas. The impact of these natural disasters is generally increasing due to factors like urbanisation, and increased global connectivity.

Biological Risks

All these risks pathogens, with epi- and pandemic potential, here mainly viral families of concern, antimicrobial resistance, pollution-driven non-communicable diseases, and illicit drug abuse are expected to increase unless effectively addressed. The combination of factors like climate change, global connectivity, and lack of effective countermeasures will likely amplify the impacts of these risks, leading to significant economic, social, and health challenges in the future. Climate change can alter the distribution and transmission dynamics of infectious diseases, increasing the prevalence of vector-borne diseases like malaria and dengue in previously unaffected regions. Global travel and trade further facilitate the rapid spread of infectious diseases across borders, necessitating robust surveillance and response systems.

AMR is exacerbated by the overuse of antibiotics in healthcare and agriculture, coupled with inadequate waste management practices that allow resistant bacteria to proliferate. The spread of AMR is a global concern, as it threatens to undermine the effectiveness of current medical treatments and increase the burden of infectious diseases. Air and water pollution contribute to a range of non-communicable diseases, including respiratory and cardiovascular conditions. Climate change can worsen pollution levels, particularly in urban areas, and exacerbate health disparities among vulnerable populations.

The global nature of drug trafficking networks, combined with socio-economic stresses from environmental changes, can lead to increased drug abuse and associated health risks. This requires coordinated international efforts to address both supply and demand. Addressing these risks requires comprehensive strategies that involve public health measures, economic policies, and international cooperation. A One Health approach, which recognizes the interconnectedness of human, animal, and environmental health, is crucial for effectively managing these biological risks. This involves integrating efforts across sectors to improve health outcomes, enhance environmental sustainability, and build resilient communities. Cross-border collaboration is essential for monitoring and controlling the spread of infectious diseases and AMR. This includes sharing data, resources, and best practices, as well as developing harmonized regulatory frameworks for antibiotic use and pollution control. Strengthening public health infrastructure is key to effectively responding to biological risks. This includes investing in healthcare systems, improving access to clean water and sanitation, and enhancing disease surveillance and outbreak response capabilities. Implementing policies that promote sustainable agriculture, reduce emissions, and support research and innovation in healthcare can mitigate the impacts of biological risks. Economic incentives for adopting best practices in industries that affect health, and the environment are also important.

By adopting a holistic and integrated approach that includes comprehensive strategies involving public health measures, economic policies, and international cooperation, we can effectively manage biological risks, mitigate their impacts, and ensure a more effective one health governance as called for by the scientific advisory mechanisms of the EC (EC, 2024 One Health governance in the European Union).

Environmental risks

The risks associated with eutrophication, marine pollution by oil and chemicals, macrolitter, and microlitter are likely to remain high, but stable in comparison to past events. In relation to macro- and microlitter, it is expected that the production of plastics will continue to increase at global level (ETC CE Report 2024/6). However, climate-related factors or inadequate mitigation efforts could exacerbate their impacts.

Technological Risks

Most of these risks disruption of essential services, Natech accidents, hydrogen fuel risks, ammonia use, renewable energy material sourcing, battery energy, and carbon capture are expected to increase due to factors like technological advancements, and increased demand for energy and materials. Climate change is expected to increase the risk of Natech accidents, due to its impact on hydro-meteorological triggers. This increased risk is location-specific and can be further exacerbated by human development in hazard-prone areas. Additionally, climate-related extreme weather events may also contribute to disruptions of essential services, potentially heightening the risk of power outages.

Geopolitical and societal risks

The risks of armed conflicts, terrorism, food insecurity in Europe, and unexpected large-scale migration flow are expected to increase significantly due to climate change and geopolitical instability. The relationship between climate change and migration is complex and multifaceted, with climate change influencing migration patterns and volume, but the link is not direct or straightforward, involving multiple interacting factors, which is reflected in the assessment that climate scenarios do not have a direct impact on migration. Hybrid threats and illicit trafficking of nuclear/radiological material may also escalate depending on global security dynamics. Addressing these risks requires coordinated international efforts focused on mitigation strategies and preparedness planning. Predicting terrorism's trajectory is difficult, but the threat landscape will continue to evolve, driven by rapid technological change. For instance, one potential example could be the use of Artificial Intelligence to support the planning and executing attacks, such as by lowering the entry barrier for the development of weapons.

The evolution of research in hybrid threats also underlines the difficulty of anticipation, but also its importance through prospective, foresight or predictive scenarios. Indeed, resilience as well as deterrence imposes to anticipate and adapt capacities to counter these threats before they occur.

Extra-terrestrial Risks

Some of these risks, such as major meteorite impact, and uncontrolled reentry or launch, are not expected to significantly increase, others, including damage from solar storms, space debris, Kessler Syndrome, attacks on satellites, attacks on space-related ground infrastructure, and technological over-dependence, are anticipated to rise due to various factors, including the growing number of objects in orbit, geopolitical tensions, and reliance on space-based services and external technologies.

The increasing risks associated with space-related hazards pose a significant threat to critical infrastructure, global economies, and human safety, with potential consequences including major damage, health risks, and economic losses. Proactive measures are essential to mitigate and manage these risks, ensuring the safe and secure use of space. The future impacts will depend on the effectiveness of these measures, highlighting the need for stakeholders to take a collaborative approach to managing these risks.

The main Category-Specific Findings are the following:

- **Cyber threats**: The direct and indirect potential impacts for the next 10 years are expected to significantly higher than past losses, with indirect impacts being more pronounced due to cascading effects on technology-reliant systems.
- **Meteorological and climatological risks**: Risks like heatwaves, cold waves, and tropical cyclones show substantial increases in both direct and indirect potential impacts, with indirect impacts being more significant for prolonged events.
- **Hydrological risks**: The direct and indirect potential impacts for the next 10 years are expected to be significantly higher than past losses, with indirect impacts being particularly severe due to disruptions to critical infrastructure and communities.
- **Geophysical risks**: Risks like earthquakes, tsunamis, and volcanoes show high direct potential

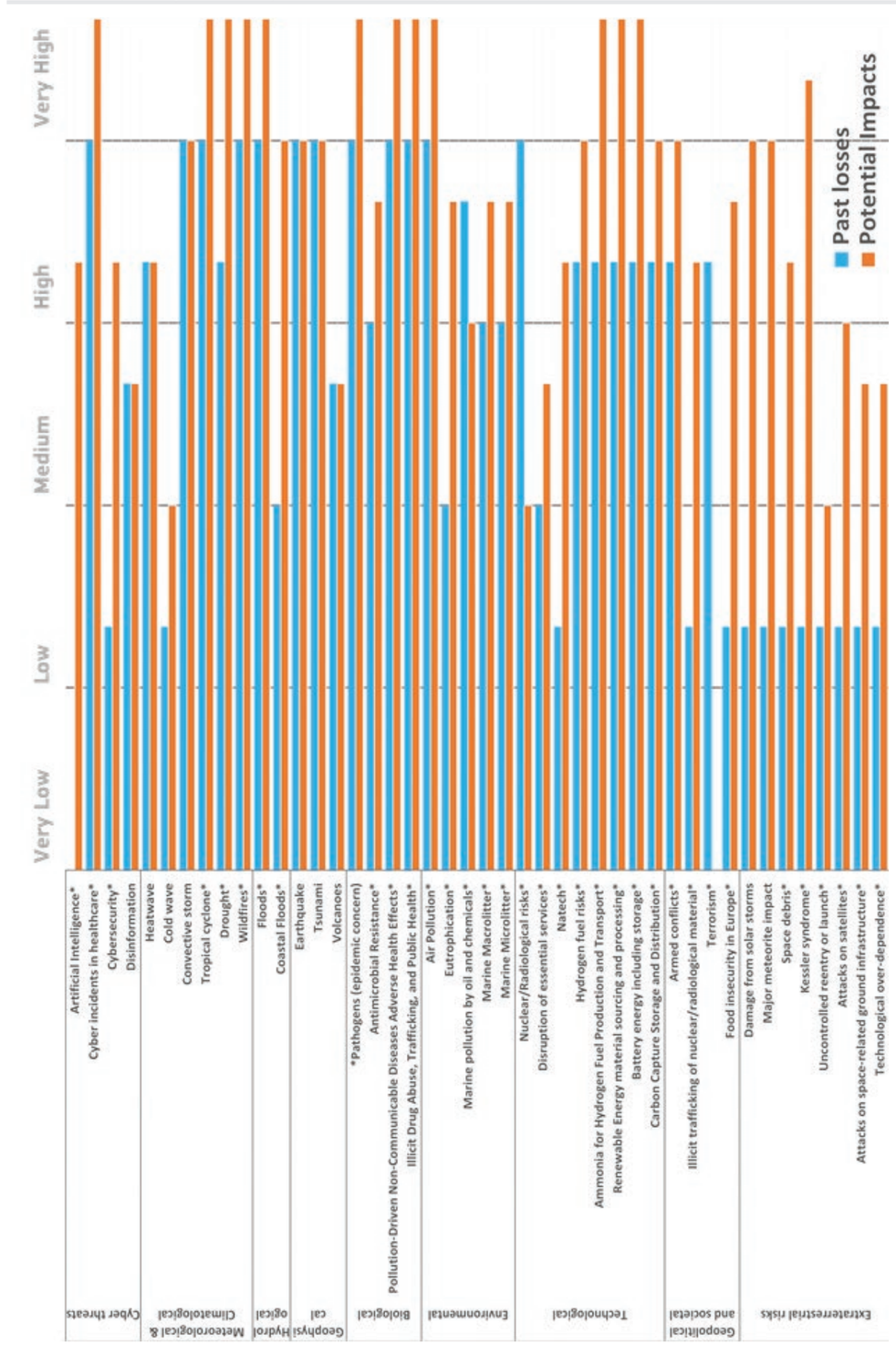
impacts, with indirect impacts being substantial due to long-term disruptions to economies and societal stability. The impacts of these risks are localised in certain areas of Europe.

- **Biological risks**: Risks stemming from pathogens, notably those with epi- and pandemic potential, antimicrobial resistance, and pollution-driven health effects show sharp increases in both direct and indirect potential impacts, with indirect impacts being more pronounced due to widespread societal consequences, while sporadic single events can yield exceptionally high direct impacts.
- **Environmental risks**: Risks like air pollution, marine pollution, and eutrophication exhibit significant increases in indirect potential impacts, with indirect impacts dominating due to cascading effects on ecosystems and human health.
- **Technological risks**: Risks like nuclear/radiological risks, disruptions of essential services, and Natech show notable rises in both direct and indirect potential impacts, with indirect impacts being especially severe due to their influence on interconnected systems.
- **Geopolitical and societal risks**: Risks like armed conflicts, terrorism, and food insecurity in Europe show significant increases in both direct and indirect potential impacts, with indirect impacts being more substantial due to long-term effects on societal stability and economic systems. Hybrid threats and illicit trafficking of nuclear/radiological material may also escalate depending on global security dynamics.
- **Extra-terrestrial risks**: Space-related risks like solar storms, space debris, and attacks on satellites show sharp increases in both direct and indirect potential impacts, with indirect impacts dominating due to disruptions to global communications and critical infrastructure.

Main conclusions

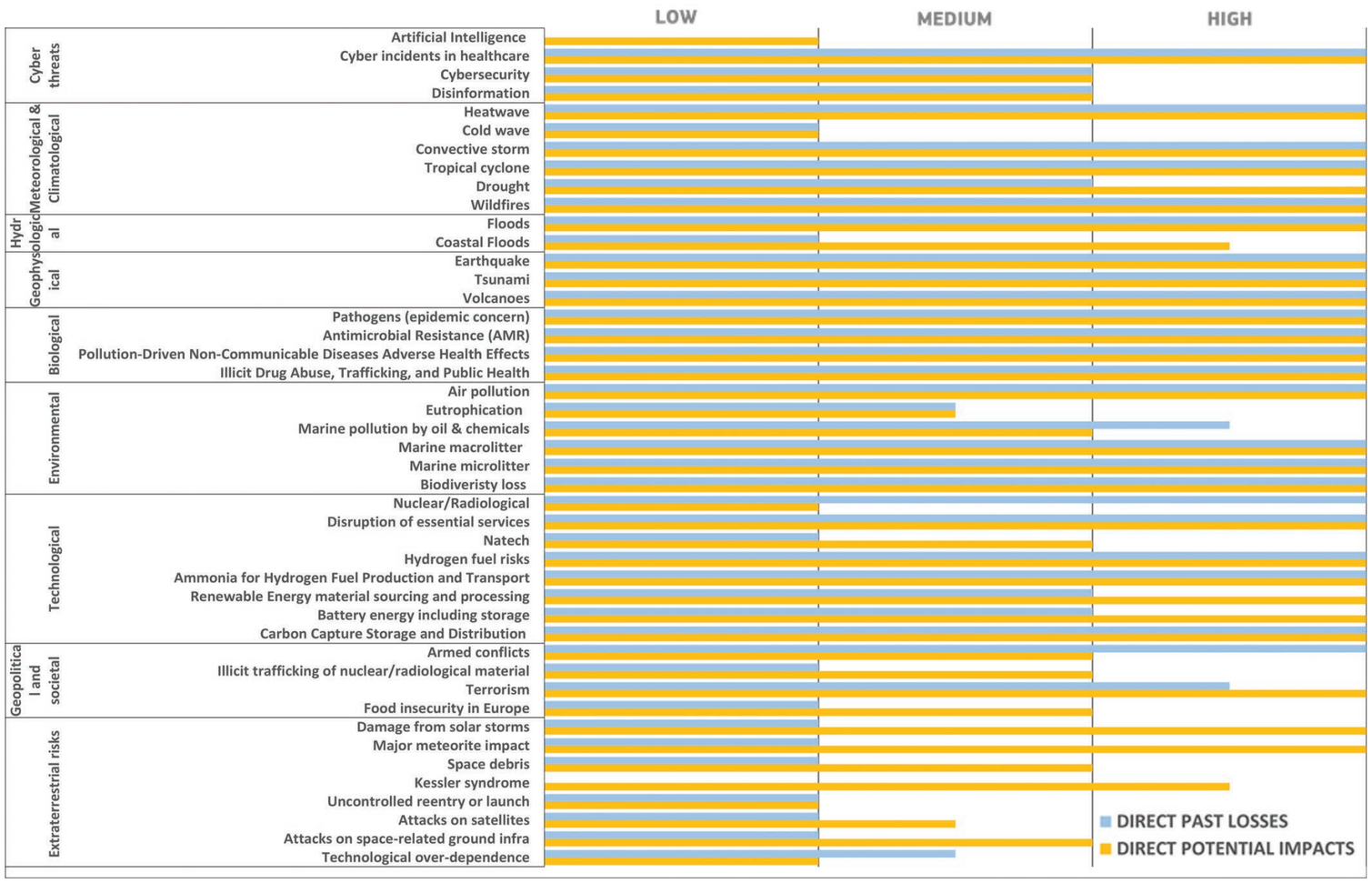
Increasing potential impacts: The analysis highlights a consistent trend of increasing potential impacts across all risk categories, with indirect impacts often outweighing direct ones.
Indirect impacts dominate: The most significant increases in indirect impacts are observed in categories such as cyber threats, biological risks, environmental risks, technological risks, and extra-terrestrial risks.
Growing complexity of risk landscapes: The analysis provides a comprehensive overview of the growing complexity of risk landscapes, where indirect consequences often have a more significant impact than immediate damages.
Interconnectedness of risks: The analysis highlights the interconnectedness of risks, where indirect consequences can have a significant impact on multiple sectors and systems.
Climate change exacerbates risks: Climate change is exacerbating the complexity and interconnectedness of global risk landscapes, making it essential to address climate change in risk management strategies.
Emerging risks require attention: The analysis identifies emerging risks such as cyber threats (e.g. AI), and space-related risks, which require attention.

Figure 5 Total (direct and indirect) past losses and potential future impacts (timeline analysis spans a 10-year period). Direct (immediate physical effects, such as infrastructure failure and casualties) and indirect (subsequent effects, like business interruption losses).



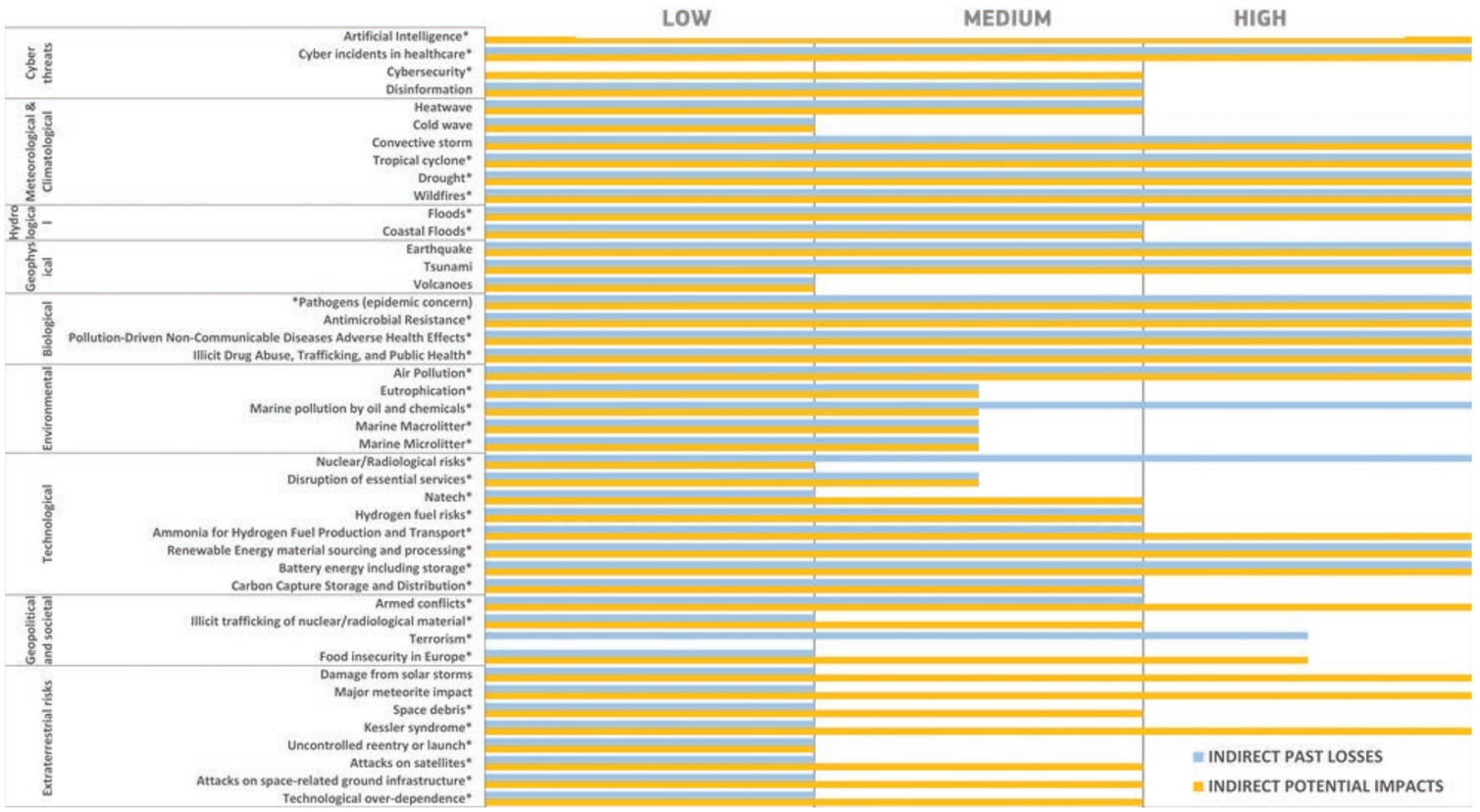
Source: Authors' elaboration.

Figure 6 Direct past losses and potential future impacts (timeline analysis spans a 10-year period)



Source: Authors' elaboration.

Figure 7 Indirect past losses and potential future impacts (timeline analysis spans a 10-year period)



Source: Authors' elaboration.

3.1.4.1. Key findings past losses and potential impacts analysis

Rising potential impacts across all risk categories

A consistent trend of increasing potential impacts over the next decade for nearly all categories of risk. While past losses (blue bars) have varied depending on the hazard, the projected impacts (orange bars) are generally higher, particularly for emerging risks such as cyber threats, environmental degradation, and technological hazards.

Indirect impacts are becoming more dominant

Figure 6 and **Figure 7** specifically highlight that indirect losses (e.g. business interruptions, long-term societal consequences) are expected to outweigh direct physical damages in the future. Categories such as biological, environmental, technological, and cyber risks show a marked increase in indirect impacts, which tend to ripple through interconnected systems and sectors.

Discrepancy between past losses and anticipated risks

Some risks (e.g. AI-related threats, space weather) show limited historical loss data but high expected future impact, especially in terms of indirect consequences. This signals a shift towards more systemic, emerging, and HILP risks that current disaster management systems may not yet be prepared to handle.

Temporal analysis supports need for forward-looking governance

The timeline analysis (10 years backward and forward) illustrates how trends in losses are accelerating due to climate change, urbanisation, digital dependency, and global interconnectivity. It also reinforces the value of utilising foresight and horizon scanning in civil protection planning.

3.1.5. Levels of uncertainty

Uncertainty in risk assessment refers to the lack of complete knowledge about current and future risks, which can stem from the inherent variability of the physical environment or from limited knowledge, measurement, or modelling capabilities. Uncertainty is present at every stage of the risk assessment process, from conceptualisation to data collection (including data imprecision) imprecision and analysis, and should be explicitly identified, documented, and communicated. It can be expressed qualitatively (expert opinion) or quantitatively (such as probability density functions), and its transparent treatment is essential for sound decision-making. It can also reflect ambiguously defined concepts or terminology, incomplete understanding of critical processes, and uncertain projections of human behaviour. (Casajus Valles et al., 2021; IPCC, 2022).

Below **Table 12** is a summary of the levels of uncertainties report by the JRC experts for each risk category, along with the reasons for such level. In **Figure 8** the graphs of the levels and percentages of uncertainties per each category.

Table 12 Uncertainty Levels and Expert Rationale for Each Risk Category (JRC experts)

Cyber Threats	
Uncertainty Level	Medium to High
Reasons	High for the rapid evolution of Artificial Intelligence and its potential risks, e.g. related to its use to develop offensive cyber capabilities. High also for the impact of cyber incidents on healthcare patients, due to limited and conflicting information. In contrast, operational cybersecurity incidents are relatively well-understood, with established methodologies for handling individual incidents. However, strategic cybersecurity and disinformation pose medium to high uncertainty levels, driven by the challenges of predicting long-term cyber risks and the complexities of disinformation threat
Meteorological & Climatological Risks	
Uncertainty Level	Varied (Low to High)
Reasons	Well-understood risks associated with heatwaves and cold waves, but higher uncertainty exists for tropical cyclones, and risks associated with droughts due to complexities in modelling impacts and cascading effects and discrepancies in projections and medium for wildfires, with uncertainty surrounding their frequency, extent, and intensity
Hydrological	
Uncertainty Level	Medium to High
Reasons	For floods, key uncertainties relate to climate and hydrological modelling limitations, the lack of harmonised data across countries, and the complexity of compound and cascading events. In the case of coastal floods, uncertainties are also driven by imprecise data, model limitations, downscaling issues, and an incomplete understanding of critical coastal processes. In both cases, scenario uncertainty related to human behaviour further amplifies the challenge.
Geophysical Risks	
Uncertainty Level	Low
Reasons	Earthquakes (Sousa & Tsionis, 2025), tsunamis, and volcanoes are relatively well-understood risks, with manageable uncertainty. However, uncertainty remains a challenge in tsunami warning systems, where rapid decision-making is required without full confirmation of a tsunami, potentially leading to false alarms. Despite the use of probabilistic hazard maps and warning systems to mitigate risks, uncertainties persist due to the need for swift decision-making.
Biological Risks	
Uncertainty Level	High

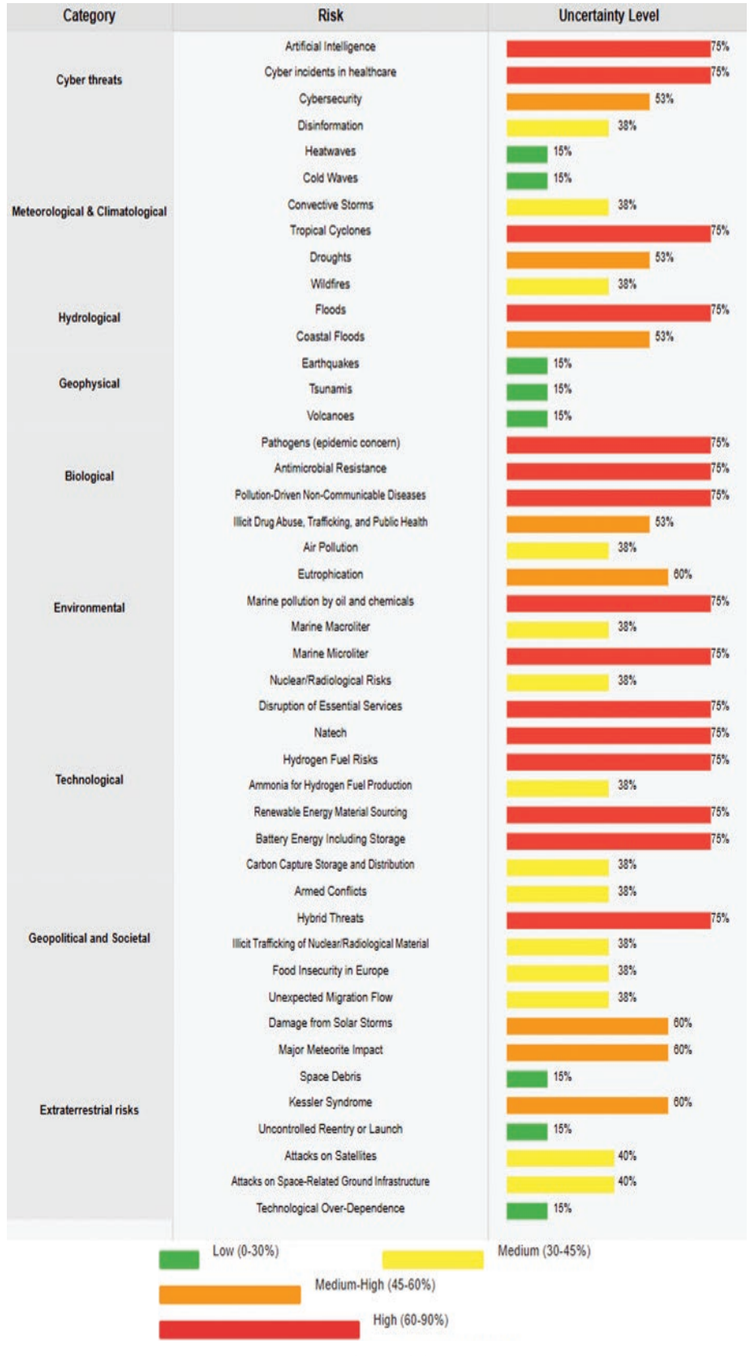
Reasons	Emergence of new pathogens, complex transmission dynamics and variability in human behaviour. Additionally, limited data on antimicrobial resistance prevalence, antibiotic use and resistance patterns in humans, animals, and the environment, particularly in low- and middle-income countries, and complex interactions between air pollution, extreme temperatures, and non-communicable diseases. Illicit drug abuse, trafficking, and public health pose a medium to high uncertainty, driven mainly by the complexity in estimating the illicit drug market size and misinformation.
Environmental Risks	
Uncertainty Level	Mainly High
Reasons	The levels of uncertainty surrounding various types of pollution are significant. Air pollution is characterised by uncertainty in emission estimation, concentration, and impacts, with the World Health Organization (WHO) defining uncertainties related to health impacts and 95% Confidence Intervals available for premature mortality. In contrast, eutrophication, marine pollution by oil and chemicals, and marine microlitter are all marked by high uncertainty, stemming from factors such as the complexity of nutrient dynamics, variability in nutrient inputs, and large uncertainties regarding future climate change impacts, energy demands, and the availability and use of safe chemical alternatives. Marine macrolitter, on the other hand, is associated with medium uncertainty, with challenges including accurate quantification, distribution, and degradation rates. Furthermore, accidents caused by human error play a substantial role in air and marine pollution, and are often unpredictable, adding to the overall uncertainty in these areas.
Technological Risks	
Uncertainty Level	Mainly High
Reasons	Uncertainty exists due to new technologies, lack of data, and complexities in risk analysis for nuclear/radiological risks, disruption of essential services (complexity of networks), and renewable energy material sourcing and processing. In addition to these factors for Natech the uncertainty is also related to the climate change projections, complexity of multi-hazard risk analysis and lack of consolidated methodologies and model uncertainties (limitations and inaccuracies in mathematical models predicting for example flood and/or earthquakes hazard behaviour and equipment/infrastructure vulnerability)
Geopolitical and Societal Risks	
Uncertainty Level	Medium
Reasons	Uncertainty exists due to geopolitical factors, evolving conflict dynamics, and clandestine nature of illicit trafficking, as well as volatility in migration patterns and food insecurity
Extra-terrestrial Risks	
Uncertainty Level	Low to Medium
Reasons	Relatively well-understood risk such as space debris, but uncertainty exists for damage from solar storms and major meteorite impacts due to unpredictability and potential for rapid escalation

Source: Authors' elaboration.

Summary by category

Overall, the uncertainty levels for various risks are varied, with high uncertainty existing for cyber threats, biological risks, and certain environmental and technological risks. Medium uncertainty exists for geopolitical and societal risks, while low uncertainty exists for geophysical risks and some extra-terrestrial risks.

Figure 8 Level of uncertainties for each risk and risk category



Source: Authors' elaboration.

3.1.6. Risks classified by potential impact and inherent characteristics

The interaction between risk characteristics such as emerging, HILP, cross-border and potential impacts can provide insight into the potential consequences for the UCPM's response and/or mitigation efforts. This includes the potential for rapid escalation (e.g., volcanic eruptions, earthquakes), and the timing and multifaceted nature of the UCPM actions in terms of response to certain risks and only mitigation for others.
In this paragraph the risks are evaluated based on their potential to trigger large-scale, transboundary crises with cascading effects, their relation with climate scenario and future potential impacts. The quantification is grounded in the analysis of JRC experts, who consider the following key factors: Cross-border risks, Climate change scenario-related risks, HILP events, Emerging risks, and potential impacts.
While the this assessment provides a structured approach to prioritising risks to the UCPM, we acknowledge that it does not fully incorporate all elementary components of standard risk assessment frameworks namely, hazard, exposure, vulnerability, coping capacity, and explicit likelihood within a defined reference period. The quantification method used here is based on expert judgement and the aggregation of key risk characteristics (cross-border, climate scenario-related, HILP, emerging) with an assigned value for potential impact. This pragmatic approach was adopted due to the lack of comprehensive and comparable data, and the challenges in applying a fully quantitative methodology across the diverse and emerging risk landscape covered by this report.

The selected risk characteristics reflect factors that are particularly relevant for the UCPM context, based on reporting requirements for the Article 6 of the UCPM, where cross-border effects, climate change implications, high-impact low-probability (HILP) events, and emerging risks are seen as threats that can rapidly escalate and overwhelm national capacities, necessitating coordinated European response. The values for potential impact (low, medium, high, very high) were determined through consensus among JRC experts, drawing on available evidence, scenario analysis, and qualitative judgement. These values are intended to provide a comparative indication of the scale of potential consequences for UCPM operations, rather than a precise prediction of losses.

We recognise that this approach does not capture the full complexity of risk as defined in the scientific literature. In future iterations, the use of a risk matrix or heatmap plotting likelihood against impact could provide a more nuanced and transparent visualisation of the risk landscape and help address concerns regarding the weighting and justification of risk categories.

Finally, the emphasis on climate change and emerging risks reflects their increasing role as drivers of systemic, transboundary, and cascading crises, as documented in recent scientific and policy literature. Climate-related hazards are projected to become more frequent and severe, while emerging risks (such as novel technologies or new biological threats) may present challenges that exceed current preparedness and response capacities.

Figure 9 presents the risks evaluated based on a combination of their inherent characteristics (cross-border, climate change, HILP, and emerging risks) and their potential impacts to the UCPM. The resulting score is then used to quantify the risk on a scale from 0 to 10 based on the following formula:
Formula:
Quantification score = (Cross-border risks + Climate change scenario-related risks + HILP + Emerging risks) + Potential impacts
Values used:
Inherent risk characteristics

- Cross-border risks = 1
- Climate change scenario-related risks = 1
- HILP = 1
- Emerging risks = 1

Potential impacts to the UCPM

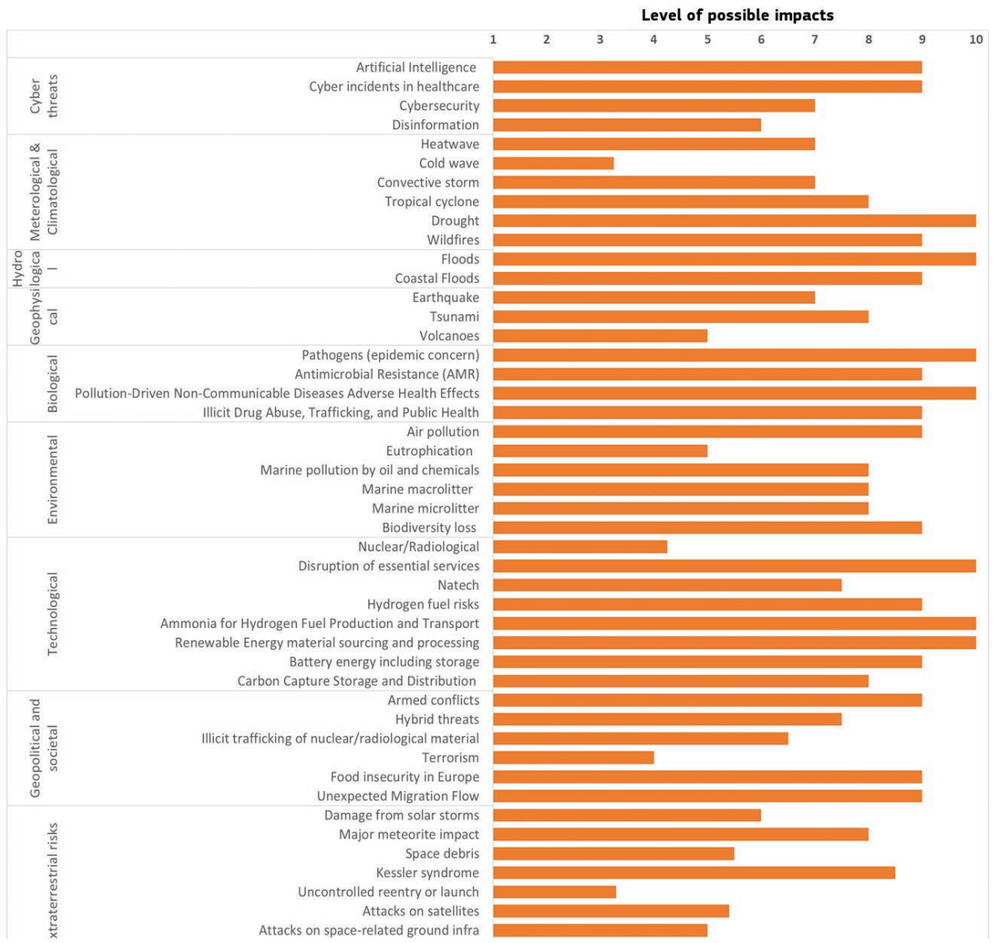
- Low = 1
- Medium = 3
- High = 5
- Very High = 6

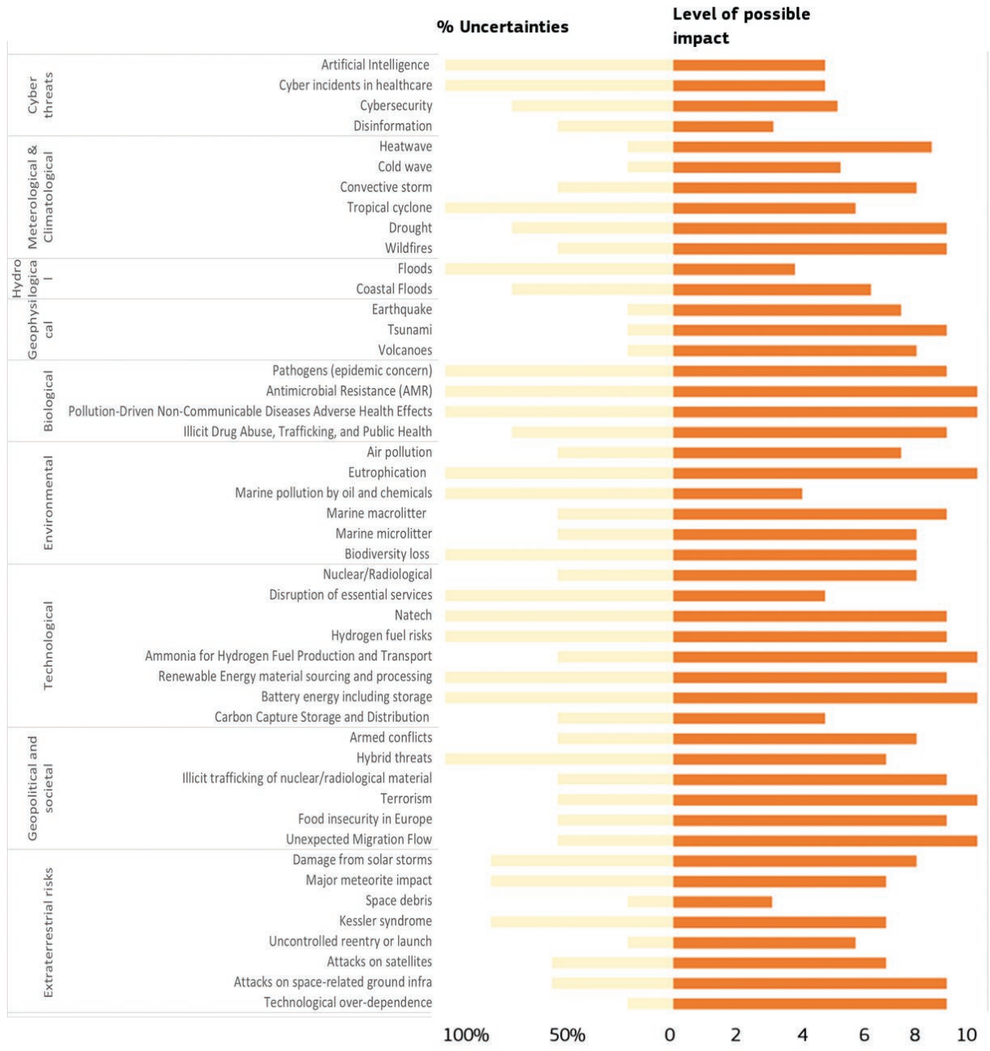
The indexes are based on the qualitative expert evaluation of past direct and indirect losses and future potential impacts (section 3.1.4 and see details, for each risk, in annex 2). When both values are high (past and future) the index assigned is 6.
Calculation: To calculate the total score, the values of the first four factors are added and then the potential impact value is added to the result.

Highest Impact Risks to UCPM Response
Based on this calculation the highest Impact Risks to UCPM Response are:
Cyber Threats
Artificial Intelligence and Cyber Incidents in Healthcare
Meteorological and Climatological Risks:
Tropical Cyclones, droughts and wildfires
Hydrological
Floods and coastal floods
Biological Risks:
Pathogens (Epidemic Concern), Antimicrobial Resistance (AMR) and Pollution-Driven Non-Communicable Diseases Adverse Health Effects
Environmental Risks:
Marine Pollution by Oil and Chemicals
Technological Risks:
Natech, Ammonia for Hydrogen Fuel Production and Transport
These risks have the potential to significantly impact the UCPM's response, including Disruption of communication and coordination systems, Impact on transportation and logistics, Damage to critical infrastructure, Risk to human health and safety.

The following risks have the highest potential impact on mitigation efforts:
Geopolitical and Social Risks:
Armed Conflicts, Hybrid Threats, Food Insecurity in Europe, Unexpected large-scale Migration Flow
Biological Risks:
Pollution-Driven Non-Communicable Diseases Adverse Health Effects
Environmental Risks:
Air Pollution
Technological Risks:
Hydrogen Fuel Risks, Renewable Energy Material Sourcing and Processing, Battery Energy Including Storage
Extra-terrestrial Risks:
Kessler syndrome

Figure 9 (Above) Quantification of the possible impacts of each risk, on a scale of 0 to 10
(Below) the same figure with also the uncertainties (%)





Source: Authors' elaboration.

3.1.7. Risk drivers and interactions

In an increasingly interconnected world, hazardous events almost never manifest in isolation. More often, they are triggered and/or amplified by other phenomena, or themselves trigger a chain of events, "cascade" of subsequent events and impacts, that may amplify the initial impact and spread disruption across multiple sectors. Climate change, for example, can increase the frequency and severity of chemical incidents, which can have significant impacts on human health and the environment. Effective response and mitigation strategies for such incidents must take into account the potential impacts of climate change and must involve cross-border collaboration and coordination. Understanding these cascading events is crucial for effective risk management and resource allocation. The analysis in this section seeks to prioritise these risks, not through a precise quantitative measure, but by evaluating their potential for systemic disruption based on the interconnections with other risks factors, such as risk drivers, other hazards or potential impacts. By analysing the interconnectedness, it is possible to identify patterns, like for example which the sectors that tend to experience a higher frequency of cascading impacts, potentially rendering them more vulnerable.

Risk driver[23] identification and analysis are important elements in assessing the probability of certain risk in the future and identifying new potential risks. For example, over the three reporting cycles for Article 6 national risk summary reports (European Commission 2017, 2021, 2024)., climate change, urbanisation and globalisation-related issues have been considered consistently as risk drivers. Other risk drivers include technological developments and geopolitical developments, global financial and economic developments, socio-economic and demographic developments, and environmental degradation[24],[25].

Cascading hazard processes describe a sequence of interrelated hazards initiated by an initial event. For example, an earthquake may trigger a landslide, which in turn causes flooding, potentially leading to further landslides. This chain reaction of hazards demonstrates the complex nature of risk scenarios (Gill et al., 2022).

Cascading impacts refer to the sequence of events in human subsystems resulting from the impact of a physical event or an initial technological or human failure. These impacts can lead to physical, social, or economic disruptions that may significantly exceed the magnitude of the initial event (Gill et al., 2022).

Compound relationships occur when two or more hazards affect the same region and/or time, resulting in impacts that differ from the sum of their individual effects. These compound relationships can manifest in various forms, including:

- A primary hazard simultaneously triggering multiple secondary hazards
- Two independent hazards impacting the same region and/or in the same time period (or in close succession). (Gill et al., 2022)

Understanding these complex interactions between hazards and their impacts is essential for comprehensive risk assessment and management strategies. It furthermore enables a more systematic and efficient risk management approach, where cross-sectoral strategies such as climate adaptation, improved governance, and technological risk assessment can enhance resilience across multiple domains. By addressing common drivers, policymakers can develop integrated measures that simultaneously reduce the hazard, exposure, vulnerability or coping capacity to multiple, interconnected risks.

Understanding Interconnections between risk drivers

The primary risk drivers across various risks include climate change, environmental degradation, urbanisation, weak governance, technological and geopolitical instability, (**Figure 10**). This Sankey diagram illustrates the intricate relationships between key driving factors, risks, and their impacts, as identified by JRC experts, highlighting the complex interdependencies and multifaceted nature of these risks. Although the diagram is intentionally detailed and dense, its purpose is to provide a visual representation of the nuanced interactions between various factors, rather than to serve as a straightforward or easily readable graphic.

Climate change emerges as a cross-cutting driver and together with **environmental degradation** significantly contribute to risks from natural hazards like heatwaves, tropical cyclones, droughts, floods and wildfires. They not only trigger direct disasters but also aggravate other risk factors.
Urbanisation increases vulnerability to earthquakes, air pollution, eutrophication, and Natech due to high population density and infrastructure stress. Cities are hotspots for cascading risks. Increased population density in hazard-prone areas means that disasters such as earthquakes, floods, and pandemics have more severe societal and economic consequences.

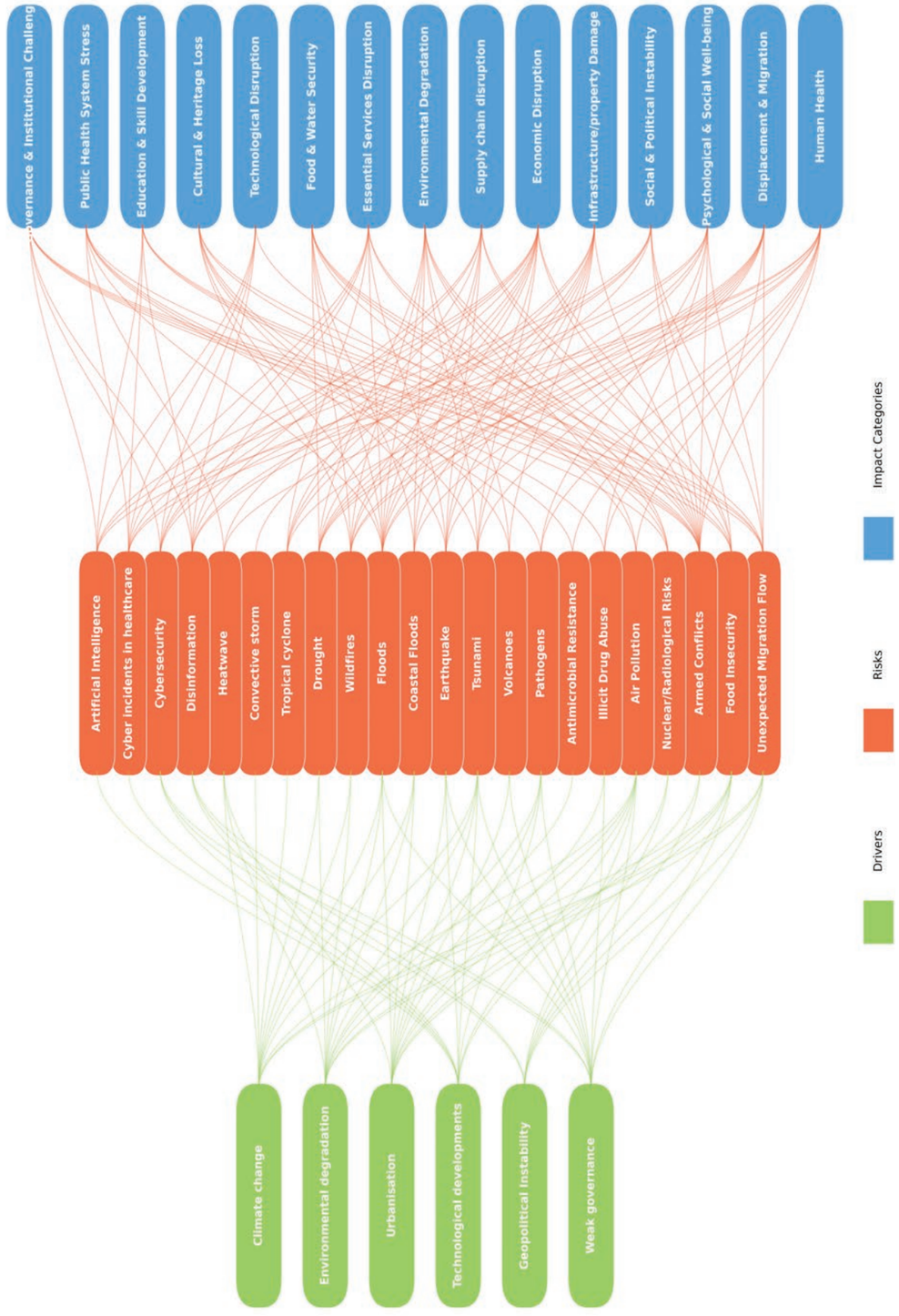
Complex risks, such as those associated with AI and Cybersecurity, arise from multiple drivers, highlighting the need for continues assessment and mitigation. These risks involve a mix of regulatory, economic, and geopolitical factors and suggest that enhancing governance and security strategies could mitigate their impact. Common drivers, such as **weak governance and geopolitical developments, influence a range of risks**, including cybersecurity, risks from natural hazards, and conflicts. Weak governance can act as an amplifier of crisis situations. Indeed, ineffective policy responses to early warning systems, poor infrastructure resilience, and inadequate emergency planning increase the likelihood of cascading failures in disaster response. Addressing these drivers through improved governance structures and international cooperation could simultaneously mitigate various risks.

23 See Terminology and definitions in 3.1.1

24 *https://civil-protection-knowledge-network.europa.eu/eu-overview-risks/risk-drivers*

25 *https://www.preventionweb.net/understanding-disaster-risk/risk-drivers*

Figure 10 Interaction between main driving factors risks and their impacts as identified by JRC experts for some of the risks analysed



Source: Authors' elaboration.

Understanding Interconnections between impacts

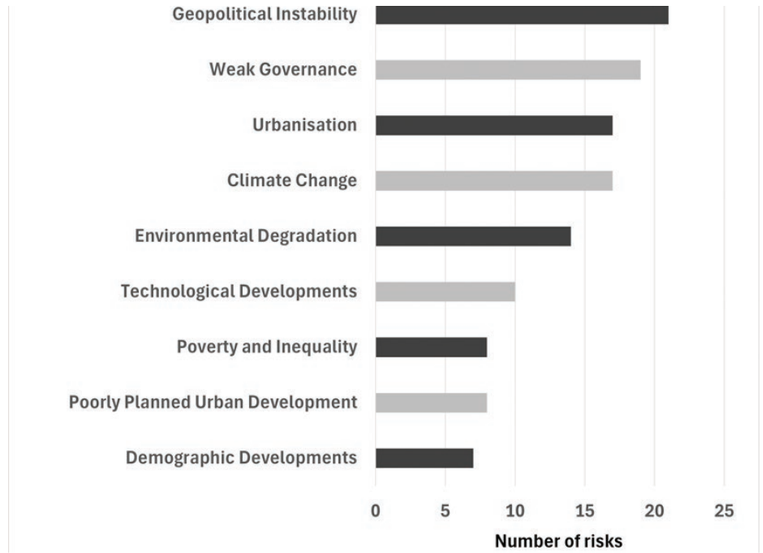
The findings highlight several **recurring impact patterns**, demonstrating that different risks whether related to natural hazards, technological, or societal often lead to similar disruptions. As shown in **Figure 10** and **Figure 11** the **most widespread impacts across multiple risks include economic disruption, human health and disruption of essential services**. These impacts arise from risks from natural hazards (floods, droughts, earthquakes), technological risks (Nuclear/radiological risks, Natech), geopolitical and societal risks (armed conflicts, migration), and environmental hazards (air pollution, food insecurity), **Figure 12**.

Economic disruption is a pervasive consequence, affecting supply chains, industries, and livelihoods across a range of risks from natural hazards, technological risks, and geopolitical risks. Addressing these disruptions requires not only enhancing financial preparedness and fostering economic resilience but also promoting sustainable practices and diversifying supply chains to reduce vulnerability. Enhancing financial preparedness and fostering economic resilience is therefore essential to mitigate the impacts of such disruptions.

Potential impacts to **human health** and **public healthcare system stress** can be triggered by, among others, air pollution, pandemics, antimicrobial resistance and food insecurity highlighting the need for stronger healthcare systems and environmental health policies. Investing in preventive healthcare, early warning systems, and community health education is crucial to mitigate these risks. Human displacement results, among others, from climate related risks, armed conflicts, and economic crises, emphasizing the importance of disaster risk reduction and migration policies. Efforts should focus on building adaptive capacity in vulnerable communities and enhancing international cooperation to manage cross-border migration effectively. **Disruption of essential services**, including energy shortages and critical infrastructure failures, can be caused by cyber threats, extreme weather events, and nuclear/radiological risks, stressing the need for resilient infrastructure and emergency preparedness. Implementing robust cybersecurity measures and integrating climate adaptation strategies into infrastructure planning are vital to ensure continuity of essential services.

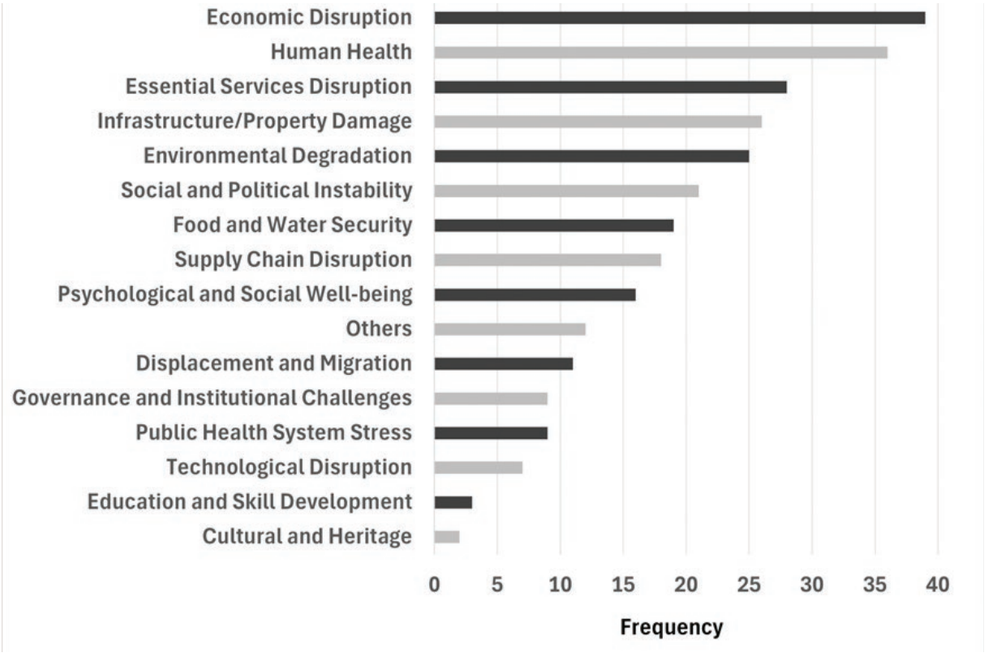
Since these impacts cut across multiple risks, policymakers should focus on solutions that address several threats at once, such as economic resilience, public health investments, and infrastructure adaptation, to maximise risk reduction and optimise resources. Adopting a transdisciplinary, holistic and coordinated approach that leverages technology, fosters cross-sector collaboration, and engages stakeholders at all levels is key to building a more resilient society capable of withstanding diverse and interconnected cross-border challenges.

Figure 11 Most common drivers triggering multiple risks as identified by the JRC experts



Source: Authors' elaboration.

Figure 12 Most common generated impacts (see section 3.1.1 for definition and categories) across the main risks as identified by JRC experts



Source: Authors' elaboration.

3.1.7.1. Summary of risk drivers and impact interactions

The findings reveal that the primary risk drivers across the 47 hazards include geopolitical instability, which is linked to 21 hazards, weak governance (19 hazards), climate change (17 hazards), urbanisation (17 hazards), environmental degradation (14 hazards), and technological advancements (10 hazards). Consequences may be varied; however, several recurring patterns of potential impacts demonstrate that different risks often lead to similar disruptions.

The analysis identified the number of risks affecting different impact sectors. The most frequently impacted sector is 'Economic Disruption,' with nearly 38 risks associated. 'Human Health' follows closely, also nearing 36 risks. 'Essential Services Disruption' are impacted by approximately 30 risks each. 'Environmental Degradation' and 'Social and Political Instability' show slightly fewer cases, 25 and 21 respectively. Other critical sectors such as 'Food and Water Security' and 'Supply Chain Disruption' have been indicated for 19 and 17 risks. 'Psychological and Social Well-being' and 'Displacement and Migration' fall within the 10-15 range. Less frequently impacted sectors include 'Public Health System Stress,' 'Governance and Institutional Challenges,' and 'Technological Disruption,' each influenced by fewer than 10 risks. The least affected areas are 'Education and Skill Development' and 'Cultural and Heritage Loss,' each with only a few associated risks. These consequences arise from natural hazards (floods, droughts, earthquakes), technological and cyber threats (AI risks, cybersecurity, Natech), geopolitical and societal hazards (armed conflicts, food insecurity migration), and environmental hazards (air and marine pollution).

3.1.7.2. Cross-risk intervention measures

The interconnected nature of these risks and impacts necessitates an **all-hazards approach, recognising the potential for compound relationships and cascading effects across sectors**. This

strategy emphasises the importance of a comprehensive risk management framework. Moreover, the whole-of-society approach is crucial, involving **collaboration across government bodies and agencies, industries, communities, and individuals** to effectively mitigate risks through shared information, resources, and expertise. These findings demonstrate the necessity of an integrated approach to risk management that addresses multiple hazards through common preparedness measures. Many preparedness measures such as infrastructure resilience, supply chain diversification, and healthcare capacity expansion apply across different types of risks. Recognising these cross-cutting strategies allows for more efficient resource allocation and risk reduction. Given the global and interlinked nature of risks, **cross-sector cooperation is essential**. Governments, private industry, and international organisations must share data, develop joint response mechanisms, and create multi-hazard policies that address interconnected threats. To enhance preparedness, future efforts must focus on:

- **Multi-Hazard Data-driven forecasting** to anticipate compound and cascading risks.
- **Community engagement** to build local resilience and empower populations to respond to crises.
- **Adaptive Governance Models** to allow for flexible risk management frameworks that account for emerging risks, including AI-driven cybersecurity threats, One health threats (EC, 2024) and geopolitical uncertainties.

By recognising which risks share common impacts, decision-makers can implement proactive, cost-effective, and scalable preparedness measures that enhance resilience against multiple risks simultaneously. This multi-hazard, all-of-society approach is key to navigating the complex risk landscape.

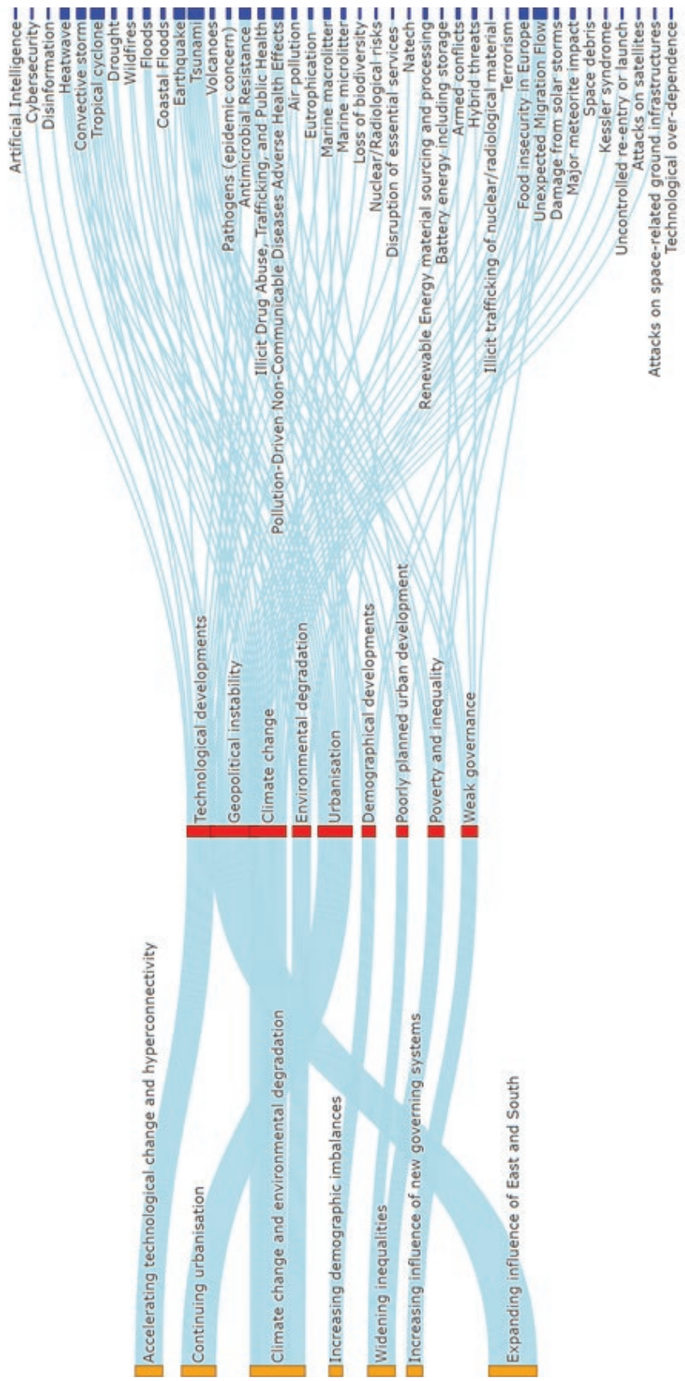
Megatrends and their impact on risk dynamics

The above-mentioned risk drivers are triggered by different factors that are studied by using foresight methods, such as megatrends analysis. Megatrends are long-term driving forces of change that are already observable now and can have a significant influence in the coming decades. JRC hosts the Megatrends Hub[1], where 14 megatrends are listed and regularly updated. Three of them are identified as the most prominent: climate change and environmental degradation, accelerating technological change and hyper connectivity, and expanding influence of East and South. By using foresight, we can thus better anticipate and prepare for future risks in a systemic way. Some of the megatrends can be similar with risk drivers, like climate change and environmental degradation has many similarities with the risk driver "climate change".

Figure 13 shows how the 14 Megatrends developed by JRC and available "**The Megatrends Hub | Knowledge for policy**"[26] (in orange) can affect the Risk driver (in red). Megatrends are possible future developments, which are already observable today but not yet fully developed. Their future development and impact have been explored and described in the JRC Megatrends Hub. The future developments of the Megatrends can affect the different risk drivers. The analysis started with listing list of most common risk drivers. In this case 7 of the 14 Megatrends were assessed to affect the risk Drivers. These risk Drivers then affect the specific risks in (blue).

26 Megatrends developed by JRC https://knowledge4policy.ec.europa.eu/foresight/tool/megatrends-hub_en

Figure 13 The 7 Megatrends developed by JRC (in orange) affecting the Risk driver (in red) for some of the risks analysed (in blue). The figure clearly illustrates the interconnections between the megatrends and the risk drivers, while the connection from risk driver to selected risks is not exhaustive, but rather examples of one or more drivers affecting individual risks. The complete list of risk drivers affecting each risk is available in Annex 2.



Source: Authors' elaboration.

These figures below are showing previous and current trends on signals that have been used to construct possible future developments. These are then used to make the different JRC Megatrends.

The Megatrend of changing security paradigm enforces the changing security / political landscape. The changing security Megatrend contains shift in the geopolitical landscape, changing conflict causalities, future battlefields and space becomes a new area of expansion.

Figure 14 The driving forces for the megarend on changing security paradigm (Figure extracted from https://knowledge4policy.ec.europa.eu/changing-security-paradigm_en)

Source: Authors' elaboration.

The Megatrend of Expanding influence of East and South enforces the Geopolitical developments Risk driver. The Megatrend contains the shift of economic power from the established Western economies and Japan towards the emerging economies in the East and South is set to continue. The Megatrend climate change and environmental degradation. It contains continued unabated, anthropogenic pollution and greenhouse gas emissions will further increase changing climate patterns.

Figure 15 Expanding influence of East and South enforces the Geopolitical developments Risk driver (Figure extracted from Expanding influence of East and South | Knowledge for policy

Source: Authors' elaboration.

The Megatrend climate change and environmental degradation.It contains continued unabated, anthropogenic pollution and greenhouse gas emissions will further increase changing climate patterns.

Figure 16 Megatrend climate change and environmental degradation (Extracted from https://knowledge4policy.ec.europa.eu/climate-change-environmental-degradation_en)

Source: Authors' elaboration.

This section has presented a thorough analysis of the potential hazards and their cascading effects facing Europe. Our examination reveals the complex web of interconnected risks and their critical relevance to the UCPM. Through a qualitative synthesis based on frequency and severity of impacts, we have mapped out key risk categories, specific risks, triggers, and impact pathways. **Table 13** provides a comprehensive summary of these findings.

The emerging thematic framework underscores the diverse nature of challenges confronting Europe. For the UCPM to effectively address future crises, a deep understanding of potential impact pathways and triggers for each risk category is essential. Some of the key areas to focus on are:

- Enhanced cross-border coordination
- Robust prevention measures
- Capacity building across vulnerable sectors

By focusing on these areas, the UCPM can significantly improve Europe's ability to anticipate, mitigate, and respond to the complex, interconnected risks that lie ahead. This proactive approach will be crucial in safeguarding the future when it comes to security and stability.

Sectors most frequently impacted

Based on the impacts assessed in this section, here are the sectors that appear most frequently for the risks covered in this report:

- **Human health** (physical and mental): This sector encompasses impacts direct and indirect health consequences, such as fatalities, injuries and affected people, but also long term health effects, patient harm due to strain on healthcare services.
- **Essential services** (energy, water, communication, transportation, etc.,): Disruption of essential services is a recurring theme as being affected by a wide range of hazards and threats.
- **Ecosystems/environment**: environmental damage, degradation or destruction due to pollution and/or contamination of air, soil and water are common impacts. Also, loss of biodiversity and ecosystem services are examples of disruption of ecosystem, which is also a recurring impact for many risks.
- **Agriculture/Food Security**: This sector is vulnerable to various risks, with direct impacts including crop losses and agricultural impacts. Indirect impacts involve food shortages, increased prices, and long-term effects on agricultural productivity.
- **Economy/Finance**: Disruption of supply chains, business interruption, financial losses, and food insecurity are common consequences.

This thematic framework highlights the diverse and interconnected risks facing Europe. By understanding the potential impact pathways and triggers for each category, the UCPM can better prepare for and respond to future crises. Prioritising cross-border coordination, prevention measures, and capacity building will be crucial for ensuring the security, safety and resilience of European citizens.

Table 13 This table shows a summary of the risks assessed, examining triggers, impact pathways and potential relevance to the UCPM. The list of precipitating factors is simply a snap-shot, and should not be seen as exhaustive, there are several other drivers, triggering hazards and impacts listed by the contributors, which can found in **ANNEX 2**.

Category	Description	Specific Risks	Precipitating Factors	Impact Pathways (Direct)	Impact Pathways (Cascading)	UCPM Relevance
Biological	Threats to public health arising from infectious diseases, antimicrobial resistance, pollution, and drugs.	Pathogens (Epidemic Concern), Antimicrobial Resistance (AMR), Pollution-Driven Non-Communicable Diseases, Illicit Drug Abuse, Trafficking, and Public Health	Emerging infectious diseases, overuse/misuse of antimicrobials, environmental/biological pollution, climate change hazards, including land-use change and human-animal interface, declining trust in vaccines and medicine, lack of access to clean water, sanitation and hygiene (WASH) for both humans and animals, inadequate health infrastructures, increasing cross border movements, war conflicts. Additional factors include urbanization, deforestation, and biodiversity loss, which facilitate the spillover of pathogens from wildlife to humans. Global travel and trade further exacerbate the spread of diseases, while socioeconomic disparities can limit access to effective healthcare and preventive measures.	Human health (mortality, morbidity), mental health, disruption of healthcare services (overload and costs), social disruption, economic and business disruptions, and societal trust.	Human health (long-term, mortality), social inequality (vulnerable groups), disruption of economic growth and development, financial crisis, supply chain disruptions, agriculture and food security impacts	Coordination of cross-border medical assistance, epidemiological surveillance, and global public health campaigns. Enhancing international cooperation for rapid response and resource allocation is critical. Implementing integrated strategies that align with the One Health approach can address interconnected health, environmental, and societal challenges, ensuring more resilient health systems and communities.

Source: Authors' elaboration.

Category	Description	Specific Risks	Precipitating Factors	Impact Pathways (Direct)	Impact Pathways (Cascading)	UCPM Relevance
Cyber Threats	Malicious activities targeting digital infrastructure and data integrity, undermining essential services and societal trust.	Artificial Intelligence-related risks, Cyber Incidents in Healthcare, Cybersecurity, Disinformation	In particular: Armed conflicts, hybrid threats and technological vulnerabilities; more general: all-hazards	Disruption of healthcare services, damage to critical infrastructure, economic disruption, manipulation of public opinion.	Economic losses, disruption of essential services, erosion of trust in democratic institutions, industrial accidents, public health crisis	Cross-border coordination of cybersecurity experts, joint response to disinformation campaigns resilience of critical infrastructure through cyber-physical security measures.
Meteorological & Climatological	Extreme weather events and long-term climate changes posing significant threats to infrastructure, health, and the environment.	Heatwave, Cold Waves, Convective Storm, Tropical Cyclone, Drought, Wildfires	Climate change unsustainable use and management of land and water resources	Human health (fatalities, injuries, affected), infrastructure and property damage, Environmental and ecosystem impacts, disruption of essential services; economic and supply chain disruptions.	Surge in energy demand, disruption of transportation, spread of diseases, including mental health, crop failures and food insecurity, business disruptions, displacements, water contamination and pollution	Deployment of firefighting resources, flood control equipment, and emergency medical teams across member states; coordinated support for drought-affected regions.
Hydrological	Water-related disasters, included in relation to sea level rise, causing displacement, economic losses, and long-term environmental damage.	Floods, Coastal Floods	Heavy rainfall, storm surges, tropical cyclones, sea-level rise, dam breaks/ levee failures.	Human health (fatalities, injuries, affected), infrastructure and property damage, environmental and ecosystem impacts, disruption of agriculture, economic impacts and damage to cultural heritage.	HHuman health (disease, including mental health), disruption of supply chains and businesses, loss of habitat and biodiversity, displacement and migration of communities.	Coordination of flood response efforts, including evacuation, provision of emergency shelter, and deployment of specialised equipment.
Geophysical	Natural disasters resulting from the Earth's geological processes	Earthquake, Tsunami, Volcanoes	Seismic activity, volcanic eruptions, underwater landslides.	Human health (fatalities, injuries, affected), infrastructure and property damage, environmental destruction (forests, habitats, crops), disruption of energy, displacement of communities.	Pollution (air, soil, water), long term environmental damage, economic and business disruptions, disruption of essential services, disruption of agriculture and fisheries, loss of cultural heritage.	Search and rescue operations, provision of emergency medical assistance, and support for long-term reconstruction efforts and Mitigation/preparedness

Category	Description	Specific Risks	Precipitating Factors	Impact Pathways (Direct)	Impact Pathways (Cascading)	UCPM Relevance
Environmental	Threats to ecosystems and human health resulting from pollution.	Air Pollution, Eutrophication, Marine Pollution by oil and chemicals, Marine Macrolitter, Marine Microlitter	Industrial and transport accidents (land and sea), waste management deficiencies, wildfires and volcanoes, extreme weather events.	Human health (premature deaths, poisoning), water quality degradation, disruption of ecosystems and loss of biodiversity, disruption of fisheries and tourism.	Human health (long term and on emergency responders), impacts of wildlife and ecosystems, accumulation hotspots, economic impacts (restoration, clean-up).	Support for environmental monitoring, pollution control efforts, and protection of vulnerable ecosystems.
Technological	Accidents and incidents involving industrial facilities, essential services, energy production, and other technological systems.	Nuclear/Radiological Risks, Natech Accidents, Hydrogen Fuel Risks, Ammonia for Hydrogen Fuel Production and Transport, Renewable Energy Material Sourcing and Processing, Battery Energy Including Storage, CCS and Distribution	Generally, all hazards. In particular: extreme weather events, armed conflicts, terrorism, organisational deficiencies	Human health (fatalities, injuries, affected), infrastructure damage, pollution and contamination, economic and supply disruptions, displacement, disruption of essential services.	Human health (casualties, disease), pollution (soil, air water), disruption of essential services, business and supply chain disruptions, displacement and exclusions zones.	Deployment of specialized CBRN response teams, support for industrial safety inspections, and management of cross-border environmental contamination. Back-up generators for energy and water supply, and telecommunication (Internet) in emergency
Geopolitical and Societal	Risks arising from conflicts, social unrest, and geopolitical challenges.	Armed Conflicts, Hybrid Threats, Illicit Trafficking of Nuclear/Radiological Material, Terrorism, Food Insecurity in Europe, Unexpected Large Scale Migration Flow	Armed conflicts, natural disasters, biological hazards, foreign hostility (State/non-State), FIMI.	Human health (fatalities, injuries, affected), infrastructure destruction, disruption of essential services, environmental devastation, social unrest.	Strain on healthcare services, mental health, economic and supply chain disruptions, political tensions and disruption, disruption of education, food insecurity, displacement and demographic changes.	Humanitarian assistance, support for border management, and coordination of international response efforts.

Category	Description	Specific Risks	Precipitating Factors	Impact Pathways (Direct)	Impact Pathways (Cascading)	UCPM Relevance
Extra-terrestrial	Threats arising from outer space, and threats to infrastructure in space or to space-related infrastructure on the ground.	Damage from Solar Storms, Major Meteorite Impact, Space Debris, Kessler Syndrome, Uncontrolled Reentry or Launch, Attacks on Satellites, Attacks on Space-Related Ground Infrastructure, Technological Over-Dependence	Solar activity, all-hazards, hybrid and armed conflicts, cyber threats	Damage or destruction of satellites, disruption of (space- and ground-based) electronic systems and their essential services (navigation, communication, surveillance), localised destruction, human health (astronauts).	Reduction quality of life, economic impacts, disruption of food production, political instability, reputational damage, loss of (autonomy in) command and control.	Mitigation of potential impact to infrastructures, coordination with ESA and space agencies, civil protection

3.1.8. Gaps/Recommendations/measures

Based on the retrospective analysis of past 10 year's events, current trends, and potential future developments over the next 10 years, as well as the results and findings of the EU institutional rreports analysed in the section 2.2.1, the important and urgent gaps for each risk category were identified. One of the key gaps identified is the need for improved cross-border collaboration and coordination in chemical incident preparedness and response. This can be achieved through the development of common standards and protocols for exposure assessment and risk assessment, as well as through the establishment of networks for sharing information and best practices. The results are presented in **Figure 17**, which shows the relevant operational, policy, and research gaps for each risk. Additionally, **Figure 18** provides the proportion of gaps for each risk category (normalised by the number of risks per each category), allowing for a comparison of the relative importance of each gap type across different risk categories. The normalisation by the number of risks per category enables a more accurate comparison of the gap distribution across categories, considering the varying number of risks within each category. This analysis highlights the areas where efforts should be focused to address the identified gaps and mitigate the associated risks.

Figure 17 Measures recommended to complement existing adaptation and mitigation measures for each risk. Research gaps are indicated in red, policy gaps in green, and operational gaps in blue.

CYBER THREATS

Artifical Intelligence

- Insufficient understanding of AI impacts on society and environment
- Lack of specific standards and codes of practice
- Widespread adoption of trustworthy AI practices across industries is needed

Cyber incidents in healthcare

- Incident characterisation in health settings; Long-term effects on patients
- Standardised reporting requirements; Cybersecurity resource allocation
- Staff awareness and training; Incident response planning and coordination

Cybersecurity

- Political willingness to invest; Lack of standardised methodologies implementation
- Correct implementation of existing methodologies and good practices

Disinformation

- Analysis of trends in climate change, migration, public health
- Lack of legal mandate to profile accounts that spread misinformation
- Lack of access to data from social media platforms

METEOROLOGICAL AND CLIMATOLOGICAL

Heatwave

- Comprehensive epidemiology of heatwaves is needed
- National guidelines lacking; Adaptation strategies for vulnerable people not in place
- Dedicated sectoral reporting schemes; Unified methodologies for risk assessments

Cold wave

No significant gaps, no specific urgency

Convective storms

- Comprehensive epidemiology is needed
- National guidelines lacking; Adaptation strategies not in place
- Dedicated sectoral reporting schemes; Unified methodologies for risk assessments

Tropical cyclone

- Need for standardised methodologies for risk assessment
- Stronger disaster legislation; National guidelines for risk assessments
- Capacity gaps in national and local disaster risk management systems

Drought

- Insufficient protocols, standards, and scientific literature
- Limited understanding of drought risk and lack of standardised impact reporting
- Accuracy, availability, and standardisation of data

Wildfires

- Understanding fuel-atmosphere interaction, predicting explosive fire behaviour, and developing wildfire behaviour models in urban-wildfire interfaces
- Planning for wildland-urban-interface (WUI) wildfires; implementation of existing policies in the WUI
- Wildfire behaviour models in use in Decision Support Systems

HYDROLOGICAL

Floods

- Inadequate data collection and analysis
- Insufficient integration of flood risk management into land use planning
- Limited real-time monitoring systems; Lack of robust early warning systems

Coastal Floods

- Gaps in scientific research for assessing and projecting sea level rise
- Lack of protocols and international cooperation for sea level rise
- Inaccurate or missing data; inadequate stakeholder engagement

GEOPHYSICAL

Earthquake

- Exposure data
- Planning and funding of mitigation measures

Tsunami

- Lack of coastal bathymetry data
- Need of standardised global loss data collection; more offshore sea level data for improved tsunami forecasting; enhanced end-to-end tsunami warning systems; and better community preparedness

Volcanoes

- Global monitoring scheme; Shared metrics and standards

BIOLOGICAL

Pathogens (epidemic concern)

- Funding in R&D on vaccines, treatments, and diagnostics; Lack of standardisation in data analyses
- Stronger global and cross-sectorial collaboration; Investments in public health infrastructure
- Improved surveillance and early detection mechanisms; Better public communication and education

Antimicrobial Resistance (AMR)

- Ineffective programmes, limited understanding of biosecurity, need for new antimicrobials, and lack of data and surveillance
- Weak regulation, inadequate supervision, and lack of international cooperation and public awareness
- Strengthening implementation of AMR interventions in human health settings

Pollution-Driven Non-Communicable Diseases (NCD) Adverse Health Effects

- Investing in research for NCD treatments; Standardising data analysis for surveillance
- Fostering international collaboration; Stronger global and cross-sectorial policy integration
- Strengthening data collection; Enhancing public health infrastructure; Increasing awareness

Illicit Drug Abuse, Trafficking, and Public Health

- Controlling precursor chemicals, understand the most effective community-based initiatives, improve research in the impact of education and economic opportunities, surveillance and monitoring, research on the benefit of promoting healthy lifestyles
- Implementing strict controls on precursor chemicals; Fostering international cooperation and coordination
- Standardising detection techniques; Strengthening community-based initiatives; Enhancing access to education and economic opportunities; Promoting healthy lifestyles

ENVIRONMENTAL

Air pollution

- Improving knowledge of health effects; Harmonising air quality modelling
- Inconsistent national and local inventories

Marine Pollution

- Monitoring of eutrophication; Long-term effects of spills; Fate of marine litter
- International cooperation and policy enforcement; Public awareness campaigns
- Data availability on vessel cargo; Efficient recycling solutions for marine litter

Biodiversity Loss

- Lack of comprehensive data on biodiversity; Poor representation of essential biodiversity variables; Need for quantitative studies on future biodiversity scenarios; Limited understanding of diverse biodiversity values
- Weak regulatory frameworks and enforcement; Lack of policy coherence and integration; Insufficient international cooperation and institutional capacity
- Insufficient data monitoring and standardised metrics; Limited public awareness; Inadequate funding and resource allocation

TECHNOLOGICAL

Nuclear/Radiological risks

- Gaps in modelling nuclear reactor phenomena after core melting; Unavailability of reliability map of nuclear risk
- Lack of harmonised policies for nuclear emergency preparedness and response
- Lack of harmonised protocols on Emergency Preparedness and Response

Disruption of Essential Services

- Complex risk landscape and interconnected systems; system complexity due to interdependencies and physical-cyber interfaces
- Unclear risk ownership and jurisdiction; difficulty in prioritising risks due to lack of consensus among stakeholders
- Knowledge fragmentation; poor communication and cooperation across sectors and countries; and inadequate data availability and comparability

Natech

- Data availability; Model availability; No consolidated analysis methodologies
- Risk awareness; Risk governance (including communication)
- Limited budget; inadequate coordination of emergency planning; and insufficient training of personnel

Hydrogen fuel risks

- Development of new accident scenarios; Research on decision criteria
- Updating of regulatory frameworks; Development of new standards
- Updating of existing standards; New training and inspection protocols; Improvement of emergency planning; Development of maintenance protocols

Ammonia for Hydrogen Fuel Production and Transport

- Improved material integrity assessments; Development of accident scenarios; Understanding climate change impacts on emergency planning
- Strengthening of standards in supplier countries; Lack of harmonisation between EU and supplier countries' regulations; Inadequate consideration of risks in land-use planning for ports and pipelines
- Upgrading management of ports and pipeline infrastructure; Inadequate emergency response planning and preparedness; Inadequate material integrity assessments

Renewable Energy material sourcing and processing

- Understand and improve sustainable material sourcing practices and develop innovative materials
- lack of comprehensive policies, inconsistent standards, and inadequate incentives for sustainable material sourcing
- Inadequate implementation of sustainable material sourcing standards, limited supply chain visibility, and insufficient training for suppliers and stakeholders

Battery energy including storage

- Development of new/updated accident scenarios for battery production and storage
- Enhanced safety standards for battery production, storage, and recycling
- Training in handling; New emergency response protocols for battery incidents

Carbon Capture Storage and Distribution

- Increase research on advanced site monitoring, pipeline standards, and environmental impacts
- Robust pipeline standards
- Inadequate site monitoring and insufficient enforcement of pipeline standards

GEOPOLITICAL and SOCIETAL

Armed conflicts

- Comprehensive data on conflict impacts; Conflict forecasting models
- Integration of quantitative data and models into decision-making
- Completeness, validation and accuracy in data on fatalities and other impacts

Hybrid Threats

- Lack of a comprehensive and integrated approach to threat assessment and management
- Reinforcing European and extra-European cooperation; Developing anticipation and deterrence strategies
- Improving communication on risks and resilience; Enhancing capacities and trainings

Unexpected Migration Flow

- Improve research on the root causes of irregular migration and the factors driving migration decisions
- Inadequate data on irregular migration and return, reception capacity, vulnerability screening
- Challenges in collecting and analysing migration data

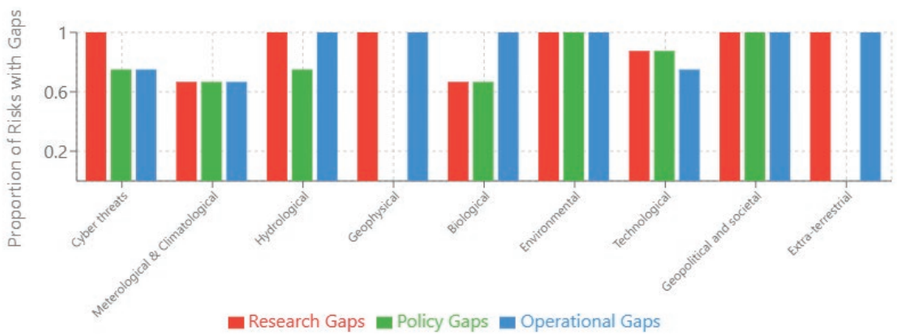
EXTRA-TERRESTRIAL

Space Risks

- Collision risks, meteor impacts, and technological dependencies to assess vulnerabilities and mitigate risks in space systems
- International sharing of information; Detailed vulnerability assessment

Source: Authors' elaboration.

Figure 18 Proportion of gaps (research, policy, operational) for each risk category (normalised by the number of risks per each category)



Source: Authors' elaboration.

3.1.8.1. Common gaps highlighted across various risks

This section highlights the common gaps across various risks, including research, policy, and operational gaps. It aims at providing with a comprehensive understanding of the gaps that need to be addressed to mitigate the impacts of these risks.
The analysis reveals several common gaps across risks, including:

Common research gaps

Methodology Limitations: Many risks, such as droughts, coastal floods, and wildfires, face challenges due to insufficient methodologies or standards for risk assessments and management.
Data Availability and Accuracy: Gaps in data availability and accuracy are common across risks like droughts, coastal floods, large-scale migration and marine pollution, hindering effective risk management
Scientific Literature: Insufficient scientific literature is a common issue for risks such as droughts and marine macrolitter/microlitter, limiting understanding and management strategies.

Common policy gaps

Lack of Standardised Guidelines: Many risks, including heatwaves, droughts, and coastal floods, lack standardised guidelines for risk assessments and management
Inadequate Funding and Resources: Insufficient funding and resources are common challenges for risks like floods, coastal floods, and antimicrobial resistance
International Cooperation: Risks such as coastal floods, marine macrolitter/microlitter and extraterrestrial risks require stronger international cooperation for effective management
Lack of infrastructure planning hinders for instance the development of hydrogen fuel projects. Without adequate grid space, pipelines, transport, and storage, producers struggle to get their products to market. Policymakers must provide guidance and support to address this issue, as a clear plan is essential to attract investors and ensure the viability of the energy supply.

Operational gaps

Limited Capacity and Resources: Gaps in operational capacity and resources are seen in risks like cyber incidents in healthcare, droughts, and antimicrobial resistance.
Data Collection and Monitoring: Inadequate data collection and monitoring systems are common issues for risks such as floods, coastal floods, and tsunamis.
Implementation of Practices: The correct implementation of methodologies and practices is a challenge for risks like cybersecurity and antimicrobial resistance.

Main recommendations

- **Data Availability and Accuracy**: efforts should be made to improve data availability and accuracy, as gaps in these areas can significantly hinder effective risk management across various domains
- **Gaps in scientific knowledge** to support management of new or modified risks
- **International Cooperation**: Strengthening international cooperation is crucial for addressing shared risks like conflicts and environmental challenges.
- **Regulatory Frameworks**: Establishing robust regulatory frameworks is essential for managing technological risks and misinformation.
- **Public Awareness and Education**: Enhancing public awareness and education can improve resilience against various risks.

3.1.8.2. Adaptation and mitigation measures recommended

For the purpose of this report, the following definitions are used:

Adaptation refers to the process of adjustment to changing conditions and their impacts, with the goal of mitigating potential harm or capitalising on emerging opportunities. This can occur in both human and natural systems, and may involve proactive measures to prepare for anticipated changes, as well as reactive responses to actual changes. In this context, health adaptation must be prioritised through national heat-health action plans, climate-resilient healthcare infrastructure, and strengthened early warning and disease surveillance systems.

Mitigation (Hazard impact): The lessening of the potential adverse impacts of a hazardous event (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability. For example, in the context of climate change, mitigation actions involve human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 2014; UNDRR, 2016). These actions are crucial to minimizing the risks associated with climate change.

Table 14 presents the measures reported by the experts that are recommended at the EU level to complement existing adaptation and mitigation measures listed in **Annex 2**.

Table 14 Measures recommended to complement existing adaptation and mitigation measures for each risk

CYBER THREATS	
Artificial Intelligence	
Mitigation: various mitigation categories and requirements, such as AI risk management, data quality and governance, human oversight, accuracy, robustness, AI cybersecurity.	
Cyber Incidents in Healthcare	
Adaptation: Focus on improving resilience through better characterisation and understanding of cyber incidents.	**Mitigation**: Establishment of a Centre for Excellence on Cybersecurity in health settings to provide training, advice, and awareness and Industry Engagement, Developing a systematic framework to identify and document common vulnerabilities in healthcare settings.
Cybersecurity	
Mitigation & Adaptation: Technological developments, infrastructure investments, Regulations to enforce correct methodologies and Awareness raising measures	
Disinformation	
Adaptation: In-house efforts at the European Commission to improve situational awareness and analysis of disinformation trends.	**Mitigation**: Make analysis of disinformation part of briefing material and policies, work on communication efforts, raising awareness. Information integrity is a vital component of the European Democracy Shield, as it is essential for maintaining trust in democratic institutions and processes

Meteorological & Climatological	
Heatwaves and cold wave	
Adaptation: Strengthening existing measures as the measures are not implemented or not equally spread across the EU	**Mitigation**: Indirectly through climate change mitigation; reducing urban heat island effects
Convective storm	
Not analysed	
Tropical Cyclones	
Mitigation & Adaptation: Infrastructure improvements, community actions, technological advancements, and support for marginalised groups. Also, diversifying livelihoods, flood protection measures, green infrastructure, early warning systems, and climate-resilient construction.	
Drought	
Adaptation: Water harvesting, water efficiency, water reuse, soil conservation, efficient irrigation systems, and climate-resilient infrastructure. Climate resilient landscape, sustainable use and management of land and water resources, early warning systems, climate services	**Mitigation**: Reduce greenhouse gas emissions to avoid worst warming scenarios. Implement efficient irrigation systems to reduce water consumption. Restore natural ecosystems, such as wetlands and forests, to maintain ecosystem services. Develop climate-resilient infrastructure, including nature-based solutions, to protect communities from droughts. Develop and implement proactive and prospective drought management strategies

Wildfires	
Adaptation: Nothing specific at EU level	**Mitigation**: Same listed for drought and floods

Hydrological	
Floods	
Adaptation: Enhance nature-based solutions, integrate climate adaptation into urban planning, and improve community involvement.	**Mitigation**: Strengthen existing measures
Coastal Floods	
Adaptation: Ecosystem-based adaptation, nature-based solutions, flood-control gates, elevating infrastructure, relocating people, and climate-resilient urban planning.	**Mitigation**: Same key measures to address climate change e.g. Transition to a low-carbon economy; enhance carbon sinks; promote sustainable consumption.

Geophysical	
Earthquake	
Adaptation: Climate change adaptation not relevant to earthquake risk.	**Mitigation**: Renovation of elements at risk, increased insurance coverage
Tsunami	
Climate change adaptation not relevant to tsunami risk	The effective mitigation measures are corresponding to those listed as indicators of the IOC Tsunami Ready Programme[27]
Volcanoes	
Climate change adaptation not relevant to volcanoes risk	**Mitigation**: Strengthen existing measures

Biological	
Pathogens (epidemic concern)	
Adaptation: Enhance public health infrastructure, strengthen surveillance systems, cross-sectoral cooperation among MSs, promote research and development, foster One Health approach, support open data sharing	**Mitigation:** Enhance vaccination programs, implement hygiene and infection control policies, strengthen international collaboration on health security, adopt a One Health approach, foster adoption of open-source software and tools for data analysis, raising awareness/education, and increase funding for infectious disease research.
Antimicrobial Resistance	
Adaptation: Enhanced cooperation between agencies, cross-sectoral cooperation among Mss, foster a One Health approach, regular monitoring of progress, and increased international cooperation, particularly with the UN, G7, G20, and quadripartite organisations.	**Mitigation**: Implement hygiene and infection control policies, strengthen international collaboration on health security, adopt a One Health approach, foster adoption of open-source software and tools for data analysis, raising awareness/education, and increase funding for AMR.

27 https://tsunami.ioc.unesco.org/en/tsunami-ready . Not all coastal communities satisfy some/all of them. The mitigation measures at local level are implemented in in a patchy manner in all basins at global level.

Illicit Drug Abuse, Trafficking, and Public Health	
Adaptation: Implement alternative development programs, enhance access to treatment and healthcare, promote community-based initiatives.	**Mitigation:** technological solutions, enhanced border controls, intelligence gathering, collaboration, capacity building, and addressing shifting health challenges to ensure effective health security.
Pollution-Driven Non-Communicable Diseases Adverse Health Effects	
Adaptation: Integrating health and nutrition policies, enhancing community resilience, and expanding access to healthy food and clean water, addressing inequalities in exposure to environmental pollutants.	**Mitigation**: Transitioning to clean technologies, strengthening enforcement mechanisms, and promoting sustainable urban development can reduce pollution and NCDs. Enhancing cross-sectoral collaboration, implementing education and awareness campaigns, and increasing funding for NCD research and innovation are also essential.
Air Pollution	
Adaptation: Not Applicable	**Mitigation** Decision Support Systems to help designing efficient and effective co-benefits policies could be developed, so that local and national authorities are better informed.
Eutrophication	
Adaptation: Increased monitoring, including the use of satellite data to complement in situ monitoring of eutrophication indicators.	**Mitigation**: reinforce the measures in place
Marine Pollution by Oil and Chemicals	
Adaptation: Increase satellite surveillance and early alerts. Substance-specific containment and clean-up techniques. Rehabilitation programs and ecosystem restoration. Development of new technologies to improve spill response	**Mitigation:** Research and development of safe alternatives to chemicals. Improve toxicity tests and regulation of chemicals before commercialisation. Create marine protected areas and risk maps to manage ship traffic. Improve safety standards and technology in the maritime sector. Enforce stricter regulations and inspections. Improve spill reporting for hazardous substances. Reducing dependence on mineral oil and phasing out hazardous chemicals
Marine macrolitter and microlitter	
Adaptation: reinforce the measures in place (including increase harmonised monitoring, research and development of new technologies, reduce production, production of more sustainable alternatives)	**Mitigation**: reinforce the measures in place

Technological	
Nuclear/Radiological risks	
Adaptation: harmonised methods and procedure for the Emergency Preparedness of radiological/nuclear accidents	**Mitigation** Harmonisation of Emergency Response methodologies (i.e., improving measurement stations arrangement, harmonisation of codes used for radioactivity dispersion and source term evaluations, general methodology for nuclear impact assessment).
Disruption of essential services	
Adaptation: invest to reduce vulnerabilities, develop emergency response plans, promote diversification and redundancy in supply chains and source systems, infrastructure hardening, implement early warning systems, strengthen cross-border policies, foster cooperation, information sharing and capacity building of workforce through training and exercise.	**Mitigation**: conduct regular risk assessments, provide resources for personnel, report potential threats, build a lesson-learned culture, collaborate with partners, develop and update business continuity plans, and decrease dependence on outsourcing, to prevent disruptions and ensure continued operation.
Natech	
Adaptation: Preparedness for beyond-design basis events, risk monitoring, climate adaptation strategy, availability of natural hazard data, early warning.	**Mitigation:** Land-use planning to limit siting of hazardous installations in natural hazard areas, adopt performance-based design in industry and ensure compliance with performance criteria, implement risk reduction measures (e.g., retrofitting, reduce hazardous inventories, use less hazardous substances, relocation).
Hydrogen fuel risks	
Adaptation: incorporate safety into equipment design, update regulatory frameworks and standards, gather data and conduct research to inform guidelines and risk assessment models, and develop training and inspection protocols.	**Mitigation**: design new infrastructure with tested mitigation enhancements, ensure explosion protection for plants, implement land-use planning and risk evaluation, map distribution networks, enhance emergency planning and response, update maintenance and inspection protocols, invest in advanced containment equipment, and develop real-time incident mapping tools, while also coordinating internationally on hydrogen release response protocols.
Ammonia for Hydrogen Fuel Production and Transport	
Adaptation: Technical standards for equipment design, international and national safety standards for ammonia handling and storage, specialised training for personnel handling ammonia to ensure adherence to safety protocols, emergency response plans and conduct drills to prepare for potential new ammonia accident scenarios.	**Mitigation**: Ensure infrastructure design incorporates proper mitigation measures, such as improved gas neutralization systems and portable scrubbers, and provide enhanced training for first responders, while also investing in capacity building, infrastructure, and equipment in supplier countries to improve emergency response and risk management.

Renewable Energy material sourcing and processing	
Adaptation: none	**Mitigation**: Development of rapid-response units for contaminated site clean-up; Research into bio-remediation techniques for material spills; Introduction of stricter international co-ordination on mining incidents.
Battery energy including storage	
Adaptation: implement international and national safety standards, design energy storage systems with safe materials and features, provide specialized training for personnel, develop emergency response plans, and conduct regular drills, while also enhancing containment design, monitoring, and maintenance, and collaborating internationally to improve mining standards and build capacity for risk management in emergency economies.	**Mitigation**: Research into faster and more effective battery fire suppression techniques, Development of standardized protocols for battery removal in emergencies. Training programs for workers and emergency responders on lithium-ion battery fires, Land-use planning criteria for battery storage sites, Introduction of stricter international coordination on mining incidents.
Carbon Capture Storage and Distribution	
Adaptation: none	**Mitigation**: Research into advanced leak-sealing technologies; Development of public risk communication strategies for CCS incidents.

Geopolitical and societal	
Armed conflicts	
Adaptation: none	**Mitigation**:
Hybrid threats	
Adaptation: Reinforcement of awareness, detection and determination.	**Mitigation**: More attribution of hybrid attacks, more democratic responses as retaliation to increase deterrence on future attacks, reinforcement of resilience means, including in the defence domain.
Illicit trafficking of nuclear/radiological material	
Adaptation: harmonised methods for deterrence, detection and response.	**Mitigation**: Harmonised concept of operation of detection and response, Rapid information sharing mechanisms among EU member states.
Terrorism	
Adaptation: none	**Mitigation**: Anticipate: Identifying vulnerabilities and building capacity to anticipate threats Prevent radicalisation by providing opportunities for young people at risk and supporting the rehabilitation of radicalised prisoners Protect by Promoting security by design and reducing vulnerabilities to protect cities and people Respond: Police cooperation and information exchange.

Food insecurity in Europe	
Adaptation: • Integrated approaches, e.g. Agroecology • Food Systems transformation (production, food environment, consumption and waste) • Behavioral actions: reduce the consumption of animal-based products and reduce food waste. • Increase resilience of agricultural systems including crop diversification, sustainable agricultural practices, water management, soil health, biotech solutions for agriculture • Digitalisation uptake: precision farming, access to services • Promote precision agriculture and breeding programmes for resilient crop varieties (more tolerant to extreme weather and more resistant to diseases).	**Mitigation**: • Food waste reduction: improve food storage and distribution. • Set-up emergency stocks • Promote healthy diets • Climate-resilient agricultural practices • Alternative protein sources • Strengthening agricultural insurance schemes • Simplification of procedures.
Unexpected Large Scale Migration Flow	
Adaptation: none	**Mitigation**: • Enhance support for addressing root causes of migration, such as poverty, conflict, and environmental degradation. • Ensure reception contingency planning is adopted across Member States. • Provide targeted support to local communities hosting large numbers of migrants, including funding for infrastructure, services, and social cohesion initiatives. • Develop communication strategies to address misinformation and promote public awareness about migration and asylum.

Extra-terrestrial	
Damage from solar storms	
Adaptation: Build up solar-storm-proof backup systems for essential services.	**Mitigation**: Build up solar-storm-proof backup systems for essential services.
Major meteorite impact	
Adaptation: None	**Mitigation**: None
Space debris	
Adaptation: none	**Mitigation**: none
Kessler syndrome	
Adaptation: Consider terrestrial backup systems for the case of widespread outage of critical space-based services.	**Mitigation**: Consider terrestrial backup systems for the case of widespread outage of critical space-based services.

Uncontrolled re-entry or launch	
Adaptation: none	**Mitigation**: None
Attacks on satellites	
Adaptation: Ensure adequate redundancy of satellite platforms and services.	**Mitigation**: Ensure adequate redundancy of satellite platforms and services.
Attacks on space-related ground infrastructures	
Adaptation: Ensure adequate redundancy of ground-based facilities.	**Mitigation**: Ensure adequate redundancy of ground-based facilities.
Technological over-dependence	
Adaptation: none	**Mitigation**: none

Source: Authors' elaboration.

3.1.8.3. Summary of risk adaptation and mitigation measures

Here a resume of some needed measures that could be beneficial for different risks:

1. **Transition to a low-carbon economy**: This measure can help mitigate climate change, which in turn can reduce the risk of air pollution, heatwaves, cold waves, droughts, floods, and coastal floods.
2. **Enhanced cooperation and cross-sectoral cooperation**: This measure can help address multiple risks, including antimicrobial resistance, illicit drug abuse and trafficking, and pollution-driven non-communicable diseases.
3. **Regular monitoring for situational awareness and risk assessments**: This measure can help identify and mitigate various risks, including cyber incidents, disinformation, and disruptions to essential services.
4. **Investment in research and development**: This measure can help address multiple risks, including cybersecurity, renewable energy, and carbon capture and storage.
5. **Implementation of international safety standards**: This measure can help mitigate risks related to hydrogen fuel, battery energy, and other technologies.
6. **Enhanced awareness and detection**: This measure can help address multiple risks, including hybrid threats, terrorism, and attacks on satellites and space-related ground infrastructures.
7. **Reinforcement of terrestrial back-up services**: This measure can help mitigate risks related to space debris, Kessler syndrome, and uncontrolled reentry or launch.
8. D**evelopment of rapid-response units for contaminated site clean-up**: This measure can help address multiple risks, including renewable energy material sourcing and processing, and carbon capture and storage.

3.1.8.4. Priority measures to address high impact risks

Following a review of the measures proposed by JRC experts to mitigate each risk, the key measures to be prioritised in order to address the high-impact risks are outlined below:

- **Implementing robust cybersecurity measures** to prevent cyber threats and protect critical infrastructure
- **Developing early warning systems** for migration, meteorological and climatological risks (such as tropical cyclones and floods), and hybrid threats (in a multi-domain individual and synthetic approach)
- **Enhancing public health system** to prevent and respond to biological risks, such as pandemics and antimicrobial resistance
- **Implementing environmental protection** measures to prevent marine pollution and mitigate the effects of air pollution and eutrophication
- **Developing and implementing safety standards for technological risks**, such as hydrogen fuel and renewable energy material sourcing and processing
- **Enhancing international cooperation** to address geopolitical and social risks, such as hybrid threats, armed conflicts and food insecurity
- **Investing in research and development** to improve our understanding of and response to extra-terrestrial risks, such as Kessler syndrome

3.2. The emergence of Earth Tipping Points

The emergence of Earth System Tipping Points (ESTP) poses a significant challenge to traditional risk assessment frameworks, underscoring the need for a revised approach to analysing and reporting on systemic, cross-boundary risks. Therefore, the Earth System Tipping Points analysis is addressed separately from other risks, in order to provide a more nuanced and effective assessment of this complex topic. Chemical incidents can have significant impacts on the environment and can contribute to the emergence of Earth System Tipping Points. Effective response and mitigation strategies for such incidents must take into account the potential long-term consequences of chemical incidents and must involve cross-border collaboration and coordination. As with other emerging threats, ESTP require a more nuanced and adaptive methodology that can effectively capture their complex, interconnected nature.

To address this challenge, further discussions are necessary to explore the development of scenarios that support comprehensive risk assessments and are tailored to the needs of policymakers. This could involve the creation of strategic foresight scenarios that facilitate coordinated responses and governance structures, enabling the prevention and preparation for complex, long-term ESTP crises with cascading impacts.

The goal of these scenarios would be to provide a robust, fit-for-purpose framework for assessing and managing the risks associated with ESTP, ultimately enhancing preparedness and resilience in the face of these emerging threats.

Some reflections on the need for methodological discussions derive from current risk guidelines:

ESTP time scales differ from short-term risks

The concept of tipping points poses a challenge to a conventional Disaster Risk Assessments, which operate within shorten time frame for evaluating past and future impacts. However, evidence from paleo-records suggests that some tipping systems, such as the Greenland ice sheet and the Atlantic Meridional Overturning Circulation (AMOC), have undergone tipping points in the past, with records dating back as far as 1.1 million years ago for the Greenland Ice Sheet. More recent examples include the subpolar gyre, with some evidence suggesting links to historical events such as Europe's Little Ice Age (1300-1850), although this is subject to high uncertainty.

While past tipping points may have occurred over centuries or even millennia, future tipping points could potentially occur on much shorter timescales, ranging from decades (e.g., coral reefs, subpolar gyre) to centuries (e.g., AMOC). This highlights the need for a more nuanced and long-term approach to risk assessment, one that can capture the potential for rapid and irreversible changes in complex systems.

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Assessing non-economic losses from ESTP

While traditional Disaster Risk Assessments focus on economic and non-economic losses, Earth System destabilisation involves disruptions to climate processes and ecosystem functioning that are difficult to measure in monetary terms. To better capture these losses, new indicators such as Earth system stability and planetary boundary thresholds could be considered, providing a more nuanced understanding of the risks and consequences associated with Earth System destabilisation.

Climate scenarios used in risk assessment for Tipping points often overlook key tipping systems. Earth System Models (ESMs) provide useful scenarios for identifying potential abrupt changes in climate components, driven by external factors like greenhouse gas increases under Shared Socioeconomic Pathways (SSPs). Although ESMs have improved in representing climate extreme events, they still lack accurate representations of all tipping systems, such as ice sheet dynamics. Nevertheless, ESMs remain valuable tools for assessing Tipping Point responses and risks, as they can visualise abrupt disruptions and timing of different Tipping Points under the latest climate models (e.g., CMIP7). Efforts are underway to develop ad-hoc models for specific Earth System Tipping Points (ESTPs), such as the Atlantic Meridional Overturning Circulation (AMOC), to better capture non-linear climate responses.

ESTPs are shifting from low-likelihood, high-impact events to high-likelihood, high-impact events. Conventional risk assessments have traditionally categorised ESTP disaster risk as extreme events with low probability and high impact. However, recent IPCC Risk Assessments have revised the threshold for plausible risk for several Tipping Systems from 4 C to 1.5 C. Notably, at least 5 of the 16 identified ESTPs are at risk of crossing irreversible destabilising barriers at global mean temperatures above 1.5 C, including the Greenland ice sheet, subpolar gyre-Barents Sea Ice, Western Antarctica, coral reefs, and boreal permafrost thaw. As a result, these Tipping Systems can no longer be considered low-probability risks, but rather a new category of high-probability, high-risk events. It is worth noting that ESTPs are included in the IPCC's "Reasons for Concern" framework, highlighting their growing importance in risk assessments.

ESTP gaps and needs (see chapter 2.2.4 more comprehensive list):

- **Acting on anticipatory governance for systemic cross-boundary and cross-sectoral risks:**

  EU policy remains active on preventing the crossing of ESTP through stringent emission reduction targets (and associated temperature trends), and action on ESTP co-drivers such as deforestation-free trade, or the promotion of carbon removals. However, there is little governance to manage the impacts if crossed tipping points, creating a security gap for Europe. Despite uncertainties, anticipatory governance would be needed to at least discuss options for preparedness. Anticipatory governance would initiate with the assessment of the risks and stronger early warning systems, to then move towards planning for resilience and adaptive responses.

- **Foresight methods for risk assessments:**

  High uncertainty in Earth system tipping processes have slowed progress in ESTP risk assessments. To move forward, innovative foresight methods are needed to better assess risks and guide governance. Scenario-setting and storyline analyses are new approaches that are currently supporting climate risk assessments such as EUCRA. Aligning Disaster Risk Management methods with on-going climate risk assessment methods may provide helpful insights to cross-border and emerging threat analyses and reports.

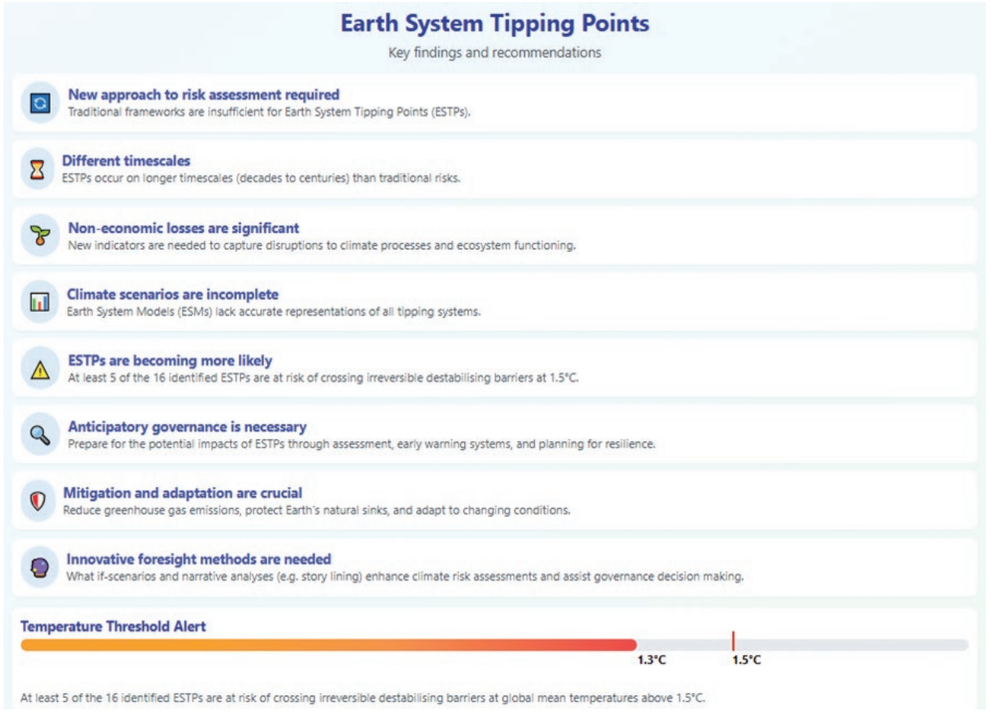
Mitigation and Adaptation measures: mitigation under the conventional risk assessment framework refers to the reduction of forcing by key drivers that lead to the risks and impacts. Adaptation instead captures the actions to withstand the impacts by ecosystems, societies and economic systems. For ESTP, mitigation would include mitigation to climate change, which focuses on GHG reductions and net zero trajectories, with special attention to the risk of overshooting. Mitigation would also include the fundamental role of Earth sinks (land and oceans), which have long buffered the increase of global temperatures by absorbing ca. Half of the globally emitted CO2 annually, and the need to protect their stability. Adaptation measures would respond to the needs of different governance clusters (food security, energy, ecosystems, infrastructure, economy, etc.) at different levels and cross-sectorial.

Main conclusions

New approach to risk assessment required: Traditional risk frameworks are insufficient for the large scale and complex impacts from Earth System Tipping Points (ESTPs).

- **New approach to risk assessment required**: Traditional risk frameworks are insufficient for the large scale and complex impacts from Earth System Tipping Points (ESTPs).
- **Different timescales**: ESTPs occur on longer timescales (decades to centuries) than traditional risks, but rapidly increasing and more variable hazards may point to approaching of ESTPs
- **Non-economic losses are significant:** New indicators are needed to capture disruptions to climate processes and ecosystem functioning.
- **Climate scenarios are incomplete**: Earth System Models (ESMs) lack accurate representations of all tipping systems, but can give information on the possible new system state after tipping.
- **ESTPs are becoming more likely**: At least 5 of the 16 identified ESTPs are at risk of crossing irreversible destabilising barriers at 1.5 C.
- **Anticipatory governance is necessary**: Prepare for the potential impacts of ESTPs through assessment, early warning systems, and planning for resilience.
- **Mitigation and adaptation are crucial:** Reduce greenhouse gas emissions, protect Earth's natural sinks, and adapt to changing conditions
- **Innovative foresight methods are needed**: Innovative foresight methods, such as horizon scanning and narrative analyses (e.g. storylining), are enhancing climate risk assessments and informing governance decision-making. These approaches are particularly valuable in addressing the current uncertainties surrounding the risks and impacts of ESTPs, and are already being successfully applied in initiatives like the EUCRA European Climate Risk Assessment
- **Proactive strategies are needed**: These methods can help identify potential tipping points, anticipate their consequences, and guide the development of proactive strategies to prevent or mitigate their effects.

Figure 19 Key findings and recommendations for ESTPs



Source: Authors' elaboration.

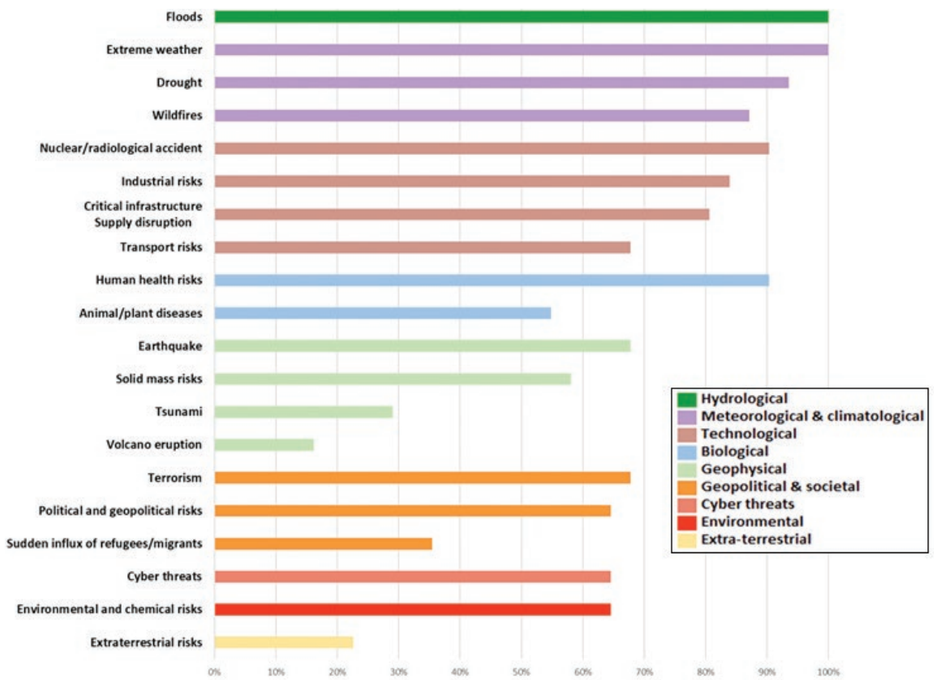
3.3. Comparative analysis: scientific, Member/Participating States

This section provides an analysis of the different approaches to risk identification and understanding employed by national Civil Protection (CP) authorities, and the scientists (JRC). Specifically, we have analysed partial findings from UCPM Article 6 reports submitted by MS/PS from the 2023 reporting cycle, which are then compared against the assessments made by the JRC experts. It is important to understand, that while the analysis/identification of risks made by MS/PS is essentially based on the situation in their respective States, the JRC experts have made their risk assessment based on the entire EU. This limits somewhat the extent to which it is possible to draw conclusions. However, there are other conclusions rather than only assessing which risks are identified as cross-border, emerging, climate-related or high impact, low probability, by the experts and MS/PS authorities. The selection of risks by the experts at the JRC reflect topics which are relevant and which are being addressed through research, mapping these against the risks that have been identified by the MS/PS assists us in the understanding of the perceptions and/or priorities of the MS/PS with respect to the science. **Figure 20** shows the identification of key risks by MS/PS in their article 6 summary report 2023. The bars have been ordered based on magnitude, and by the risk categories used in this report, and visualised using the different colours.

Technological risks show a particularly interesting alignment, with both levels highlighting nuclear/radiological risks, disruption of essential services, and Natech (natural hazard triggered technological) accidents. The assessments also reflect emerging concerns related to renewable energy and hydrogen fuel risks.

Geopolitical and societal challenges include armed conflicts, terrorism, and migration flows, with MS/PS reports adding nuanced concerns such as societal disruption and politically motivated violence. Finally, the inclusion of extra-terrestrial risks in both assessments underscores the evolving nature of civil protection concerns, encompassing threats from solar storms, space debris, and potential impacts on satellite infrastructure.

Figure 20 The percentage of MS/PS that have identified the risks on the vertical y-axis as key risks in their article 6 summary report 2023. The bars have been ordered based on magnitude and by the categories used in this report, and visualised using the different colours.



Source: Authors' elaboration.

Table 15 Risk terminology mapping based in the categories and risks assessed by the JRC experts, and the risks reported by MS/PS in the context of their article 6 summary reports.

Category	JRC expert assessed risk	Examples of UCPM MS/PS identified key risks
Cyber Threats	Artificial Intelligence-related Risks Cyber incidents in healthcare Cybersecurity Disinformation	Cyber-attacks on essential services (e.g. governmental, critical, energy) Artificial Intelligence Erosion of privacy Block-chain technology and cryptocurrency Cyber-attacks targeting information availability, integrity and confidentiality Breach of security of information systems and networks (including cyberattacks) Disinformation on various topics (e.g. climate change)
Meteorological & Climatological	Heatwave Cold wave Convective storm Tropical cyclone Drought Wildfires	Heatwaves Cold waves Extreme temperature Storms Convective events Extreme weather Drought Forest fire Wildfires
Hydrological	Floods Coastal Floods	Floods Flash floods River flood Coastal flood Special flood (as a result of disruption of water bearing infrastructure) Urban flooding Inland water
Geophysical	Earthquake Tsunami Volcanoes	Earthquake Tsunami Volcanoes
Biological	Pathogens (epidemic concern) Antimicrobial Resistance Pollution-Driven Non-Communicable Diseases Illicit Drug Abuse, Trafficking, and Public Health	Pandemic Anti-microbial resistance Epidemics/health risks Infectious diseases Vector-borne diseases Waterborne diseases Highly virulent diseases Infection driven by antimicrobial resistance
Environmental	Air pollution Eutrophication Marine chemical pollution Marine macrolitter Marine microlitter Biodiversity loss	Air pollution Water pollution Soil pollution Marine pollution Biodiversity losses Invasive species Ocean acidification
Technological	Nuclear/Radiological risks Disruption of essential services Natech Hydrogen fuel risks Ammonia for Hydrogen Fuel Production and Transport Renewable Energy material sourcing and processing Battery energy including storage Carbon Capture Storage and Distribution	Nuclear/radiological accidents Accident with a radiation source Industrial accidents Disruption of essential services (energy, communication, water, transport) Natech Hydrogen supply failure Fires linked to new generation rechargeable batteries Seveso accident
Geopolitical & societal	Armed conflicts Hybrid threats Illicit trafficking of nuclear/radiological material Terrorism Food insecurity in Europe Unexpected Large-Scale Migration Flow	Armed conflicts Hybrid risks Terrorism Security policy tension Large-scale migration Mass migration Food supply disruption Societal disruption Politically motivated violence

Extra-terrestrial	Damage from solar storms Major meteorite impact Space debris Kessler syndrome Uncontrolled reentry or launch Attacks on satellites Attacks on space-related ground infrastructure Technological over-dependence	Space incidents Space weather Solar storm Super solar storms Space debris Uncontrolled reentry of space objects and debris

Source: Authors' elaboration.

Table 16 illustrates the differences by risk category JRC expert evaluations and the views of UCPM MS/PS in their article 6 summary reports. While the JRC adopts a systemic, EU-wide lens that emphasizes cross-border impacts and emerging threats, MS/PS focus on risks deemed most relevant to their national contexts and operational needs. Understanding the gaps in the assessments is necessary in order to foster a cohesive and effective EU-wide civil protection strategy that balances localised concerns with transboundary resilience.

The JRC and MS/PS exhibit notable differences in their risk assessments across various categories, reflecting their distinct perspectives and priorities. For cyber threats, the JRC assigns a high cross-border relevance (100%), emphasizing the interconnected nature of digital infrastructure and transnational attack vectors. In contrast, MS/PS rate this aspect much lower (26%), potentially focusing on immediate national cybersecurity priorities and possibly underestimating EU-wide cascading impacts. Similarly, hydrological risks show divergence, with the JRC highlighting them as emerging risks (100%) driven by climate change and novel flood patterns, while only 26% of MS/PS consider them to be emerging risks. This divergence can probably be explained by the geographical scope of the different assessments, JRC experts considering EU wide, while MS/PS considering the countries, and that significant changes in flood patterns may not yet be evident in all MS/PS. Meteorological and climatological risks demonstrate partial alignment, with both parties recognising cross-border relevance but due to them being systemically cross-border.

For geophysical risks, the JRC emphasizes high-impact, low-probability events like catastrophic multi-country earthquakes (100%), while the response rate by MS/PS is reflective of the variation across European countries in exposure to these hazards (earthquakes, tsunami, volcanoes).

Extra-terrestrial risks highlight the most pronounced differences, with the JRC considering global-scale impacts such as asteroid strikes (100%), while MS/PS rarely identify such events in their reporting.

Furthermore, data from Article 6 submissions indicate a relatively stronger focus on known, recurring hazards such as floods and wildfires. In contrast, JRC scientific assessments emphasize emerging threats with multi-sectoral impacts, such as hybrid risks, technological convergence failures, and critical infrastructure vulnerabilities.

In terms of cross-border dimensions, while both MS/PS and JRC assessments acknowledge them, the framing differs. MS/PS tend to associate cross-border risks with direct geographical spillovers (e.g., wildfires, floods, epidemics), whereas the JRC analysis includes systemic risks that propagate via economic, technological, or ecological interdependencies. This broader definition suggests that some MS/PS may underestimate the potential cross-sectoral ripple effects of localized events.

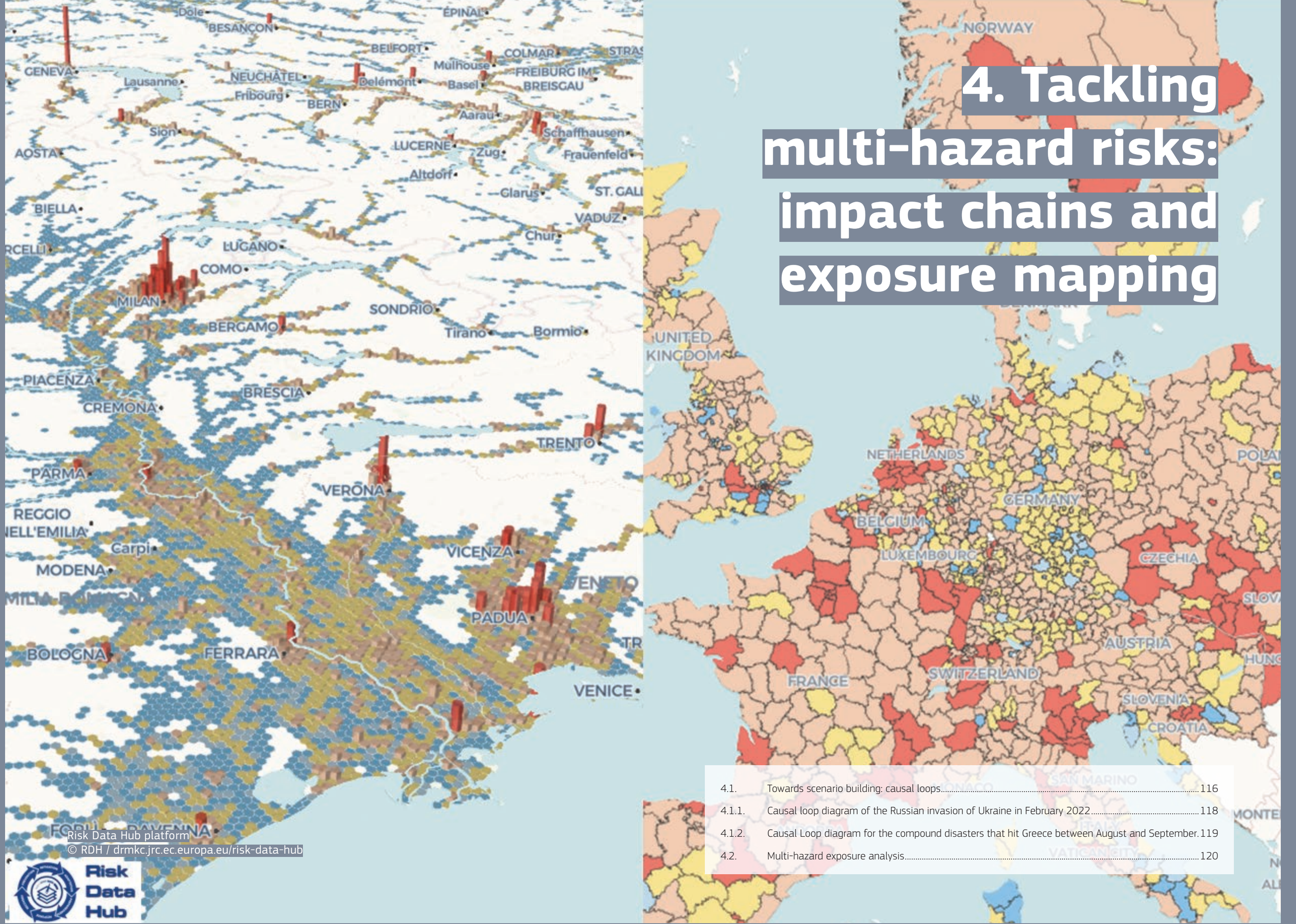
Table 16 Comparison of the basic characteristics of the risks assessed by risk category. Particular close matches are marked in green, and mismatches in red. The percentages represent the share of risks—by category—assessed by JRC experts as cross-border, emerging, climate-related, or HILP events. The right-hand column, UCPM MS/PS, shows the percentage of Member States and Participating States that have identified risks in each category as cross-border, emerging, climate-related, or HILP.

Category	Risk characteristic	JRC expert assessment	UCPM MS/PS view
Cyber threats	Cross-border	100%	26%
	Emerging	75%	23%
	Climate-related	50%	3%
	High impact low probability	50%	6%
Meteorological & Climatological	Cross-border	100%	68%
	Emerging	33%	42%
	Climate-related	100%	90%
	High impact low probability	17%	16%
Hydrological	Cross-border	100%	71%
	Emerging	100%	26%
	Climate-related	100%	87%
	High impact low probability	100%	23%
Geophysical	Cross-border	100%	35%
	Emerging	0%	0%
	Climate-related	33%	0%
	High impact low probability	100%	42%
Biological	Cross-border	100%	65%
	Emerging	100%	23%
	Climate-related	100%	55%
	High impact low probability	75%	13%
Environmental	Cross-border	100%	42%
	Emerging	100%	23%
	Climate-related	83%	19%
	High impact low probability	17%	13%

Technological	Cross-border	88%	90%
	Emerging	100%	42%
	Climate-related	75%	55%
	High impact low probability	63%	68%
Geopolitical & societal	Cross-border	100%	42%
	Emerging	100%	35%
	Climate-related	50%	23%
	High impact low probability	83%	23%
Extra-terrestrial	Cross-border	100%	10%
	Emerging	56%	3%
	Climate-related	11%	0%
	High impact low probability	33%	6%

Source: Authors' elaboration

4. Tackling multi-hazard risks: impact chains and exposure mapping



4.1. Towards scenario building: causal loops 116

4.1.1. Causal loop diagram of the Russian invasion of Ukraine in February 2022 118

4.1.2. Causal Loop diagram for the compound disasters that hit Greece between August and September. 119

4.2. Multi-hazard exposure analysis 120

Chapter 3 presents a comprehensive analysis of Europe's current and emerging risk landscape, examining risks through scientific assessments, Member State reporting, and the growing concern around Earth System Tipping Points. A key takeaway from this synthesis is the systemic nature of many risks, characterised by interdependencies, cascading effects, and compound dynamics that highlight the limitations of traditional siloed approaches to risk management. Building on this foundation, Chapter 4 examines specific high-impact events through concrete case studies, illustrating how isolated risks can evolve into complex, multi-hazard crises. Through concrete case studies, we demonstrate how isolated risks can evolve into complex, multi-hazard crises, highlighting the critical need for integrated scenario-building, multi-hazard exposure mapping, and hot-spot identification in Europe's preparedness strategies.

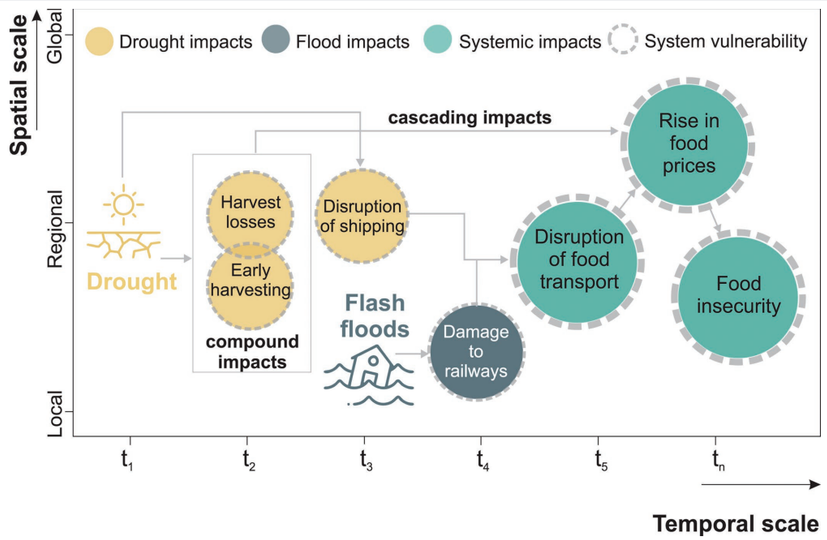
The UNDRR (2020a, p. 53) defines "multi-hazard" as encompassing two key aspects: (1) the selection of multiple major hazards a country faces, and (2) contexts where hazardous events may occur simultaneously, cascadingly, or cumulatively over time, with interrelated effects. For instance, natural hazards such as landslides, earthquakes, and tsunamis often interact or trigger related processes, reinforcing the use of the term "multi-hazard," which is closely associated with "multi-risk" in various studies (e.g., Albulescu et al., 2024; Marzocchi et al., 2012; Gallina et al., 2016).

Traditional single-risk assessments may not adequately capture the complexity of situations where multiple hazards interact and potentially lead to cascading effects. Therefore, a shift towards a multi-hazard perspective is necessary to better understand and manage the risks originating from multiple hazards and their interactions.

Dynamic vulnerability refers to the evolving susceptibility of communities and systems to hazards over time, influenced by factors such as social, economic, and environmental changes. In the context of multi-hazard risk, where multiple hazards may occur simultaneously or sequentially, understanding dynamic vulnerability is crucial for effective disaster risk management.

The interplay between multiple hazards and evolving vulnerabilities creates complex scenarios that are difficult to predict and model. This complexity poses a challenge in understanding and addressing the full spectrum of risks (de Ruiter, M. C. et al. 2022). The following **Figure 21** illustrates the increasing complexity and realism needed to assess and manage interconnected and dynamic risks effectively.

Figure 21 From multi-hazard to multi-risk



Source: Authors' elaboration De Brito, et al., 2024

In this chapter we address the complex topic of multi-hazard risk through two approaches:

- **Scenario building illustrated with causal Loop diagrams**: which capture the dynamic relationships between multiple hazards, vulnerabilities, and societal responses. They also allow understanding cascading effects, feedback loops, and interdependencies in systems.
- **Multi-hazard exposure analysis**: which quantifies and maps the spatial and temporal exposure of assets, people, and systems to multiple hazards providing a baseline data for prioritising risk reduction efforts and resource allocation.

4.1. Towards scenario building: causal loops

In the area of Disaster Risk Management, scenario building serves as a critical approach to analysing and preparing for multi-hazard risks. By constructing plausible narratives that account for interconnected hazards, scenario building enables policymakers and planners to explore potential outcomes, assess vulnerabilities, and devise strategic interventions. This approach provides a framework for anticipating cascading impacts, understanding system dynamics, and identifying leverage points for risk reduction and resilience building.

The EU-wide scenario-building and gap analyses are instrumental in shaping EU policies and operations and in enhancing DRM in a multi-hazard context. Over the past two years, DG ECHO in collaboration with experts from EU MS, UCPM PS and the JRC, has developed ten comprehensive disaster scenarios[28]. These scenarios encompass a range of potential disasters, including natural and man-made hazards, and are designed to reflect the evolving risk landscape in Europe. The insights gained from these scenarios will inform the UCPM's strategic planning, leading to more targeted prevention, preparedness and response measures. The next phase of the scenario-building initiative focuses on implementing the findings and recommendations by creating more detailed and actionable plans for DRM and resilience. This includes developing operational playbooks for practical application, enhancing planning processes, and identifying additional synergies with ongoing efforts in risk analysis, foresight, and anticipation.

To effectively develop and analyse such scenarios, visual tools that capture the complexity of system interactions are essential. Among these tools, Causal Loop Diagrams (CLDs) are a structured, intuitive way to map the interplay of variables within a system, illustrating feedback loops, dependencies, and potential cascading effects (Poljansek, et al., 2024). These loops describe the system's behaviour and are used as hypotheses to explain its dynamics. The causal or Bayesian network framework extends this visual approach by incorporating probabilities, allowing for the exploration of intervention effects within a decision context (Deutsch et al., 2024; van Westen et al., 2024).

CLDs help us visualize complex systems not as linear and static, but as circular and dynamic, capturing the essence of how variables influence one another over time (Richardson 1986, Dianat, et al., 2021). System dynamics has its roots in control theory and is particularly proficient in dealing with the intricacies of complex systems, including non-linearities, time-delays, and intricate multi-loop structures. Through system dynamics, we can simulate strategies and perform extensive trade-off analyses, which are critical in policy-making and system management. In DRM, CLDs can be particularly powerful, offering a structured way to map out the interplay between various factors, such as environmental triggers, societal responses, and economic repercussions, and to explore the feedback mechanisms that govern these interactions.

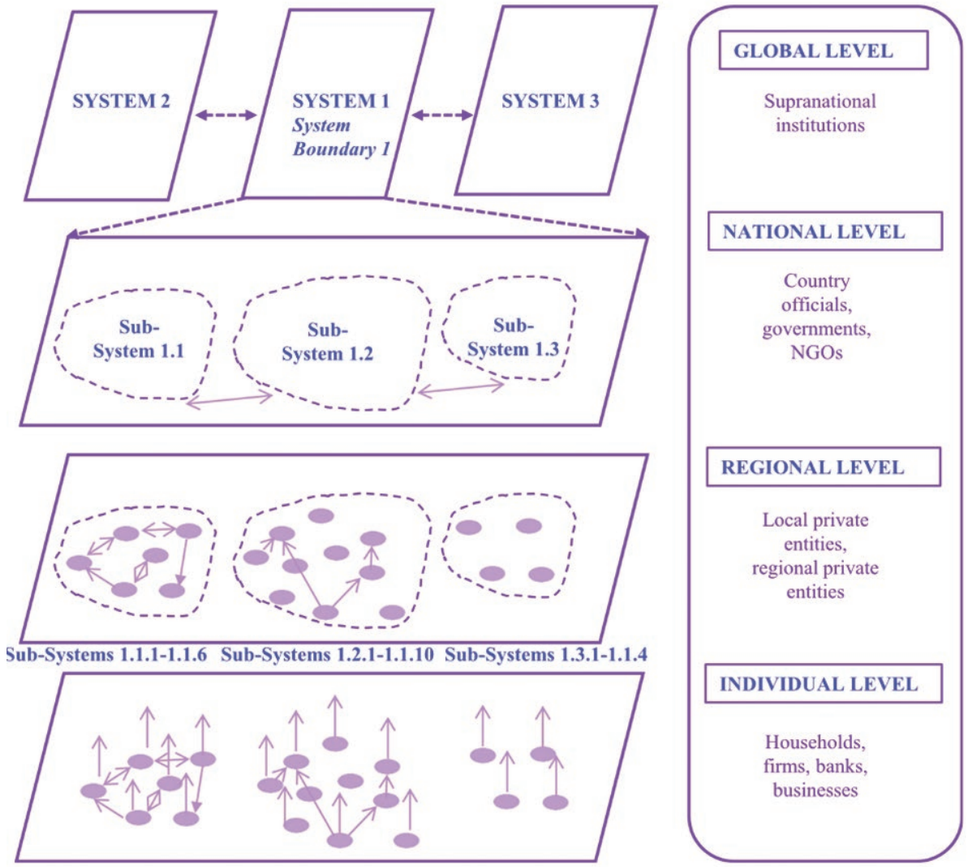
28 Disaster scenarios developed by DG ECHO, JRC with UCPM MS/PS New Union-wide disaster scenarios developed | UCP Knowledge Network (https://civil-protection-knowledge-network.europa.eu/news/new-union-wide-disaster-scenarios-developed)

By providing a view of system dynamics, CLDs enable the creation of more comprehensive disaster scenarios. They allow planners to anticipate how changes in one part of the system can ripple through others. CLDs also serve as intuitive tools for communicating complex relationships among hazards and vulnerabilities to diverse stakeholders. Their visual nature makes it easier for different stakeholders to discuss and collaborate on risk management strategies, ensuring a shared understanding of potential challenges and solutions.

To create a CLD, first select a theme (e.g., a disaster like flooding) and define a time horizon. This shapes the system's boundaries, ensuring focus and managing complexity. A system is essentially a compilation of interrelated components that synergise to achieve a common objective as shown in **Figure 21**.

Systems—physical, social, biological, economic, technological, or political—are open, with no feedback, or closed, with feedback loops shaping future actions. In a CLD, variables should represent patterns of behaviour, not specific events, and align with the issue's time horizon. For example, in an irrigation model, variables like irrigated area, increase rate, and discard rate are endogenous, while exogenous variables lie outside the system boundary. These graphs, with nodes representing different risk factors and edges denoting relationships, can be directed or undirected, with the latter's width proportional to interaction intensity.

Figure 22 System definition in terms of its constituents, from single households to international institutions.



Source: *Hochrainer-Stigler et al. 2023*

Creating a CLD involves identifying reinforcing loops, which amplify changes, and balancing loops, which stabilise the system, each defined by an even or odd number of negative links, respectively.

These loops should account for unintended effects and stay aligned with the theme. In closed systems, positive feedback promotes growth, while negative feedback maintains equilibrium, as seen in population growth and thermostatic temperature regulation. For instance, in a food security context, negative feedback loops can occur as mechanisms that stabilise the system. One negative feedback loop involves food production and agricultural expansion. As food production increases, more land is needed for farming. However, as land becomes scarcer or over-farming damages the environment, land expansion slows, limiting growth. Similarly, rising food production can lead to increased waste due to supply chain issues, consumer behaviour, or overproduction. In response, efforts to reduce waste—such as improved management, storage, and awareness—help balance food production and waste, enhancing food security (Morales-Muñoz, et al., 2020).

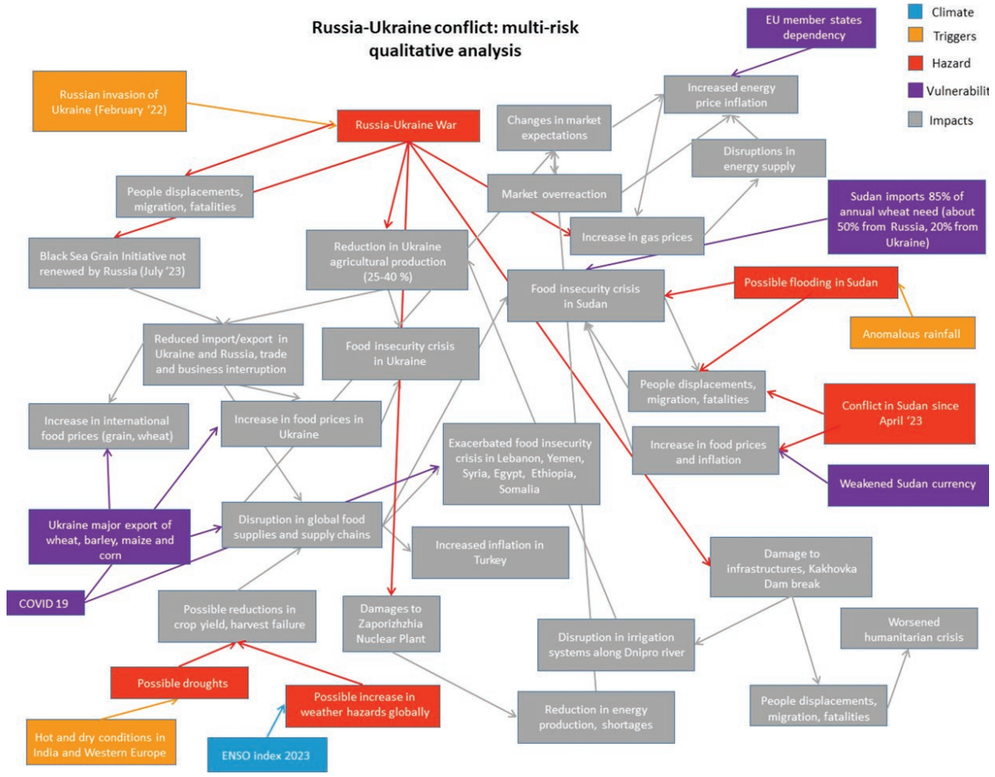
4.1.1. Causal loop diagram of the Russian invasion of Ukraine in February 2022

The Russian invasion of Ukraine in February 2022 has had severe and wide-ranging impacts and led to a complex chain of cascading events as shown in **Figure 23**. The invasion sparked a devastating war, leading to significant human displacement and loss of life. This conflict has been intensified by vulnerabilities such as the economic fragility following the COVID-19 crisis and Ukraine's critical role as a significant exporter of agricultural staples like wheat, barley, maize, and corn (Kuhla, et al., 2024, Liu, et al., 2023). The disruption of the Black Sea Grain Initiative in July 2023, due to Russia's decision not to renew it, has compounded the challenges faced by Ukraine's agricultural sector, which already saw a production decline of 25-40% because of the war. This has had substantial repercussions for Ukraine's economy, as well as for EU MS relying on these essential imports.

Moreover, the effects of sanctions, energy disruptions, and the war itself have led to a cycle of increasing energy prices, further supply interruptions, and sustained inflation. The resulting trade and business interruptions have exacerbated food insecurity in countries ranging from Lebanon to Sudan, where the reliance on wheat imports makes them particularly vulnerable to supply shocks. Sudan, for instance, which imports approximately 85% of its wheat, has been hit hard by the dual impact of reduced grain availability and the El Nino-Southern Oscillation (ENSO)-induced extreme weather conditions, leading to flooding and further agricultural distress. These factors, alongside a weak currency and rampant inflation, have plunged the country into a severe food insecurity crisis. Furthermore, the war has led to energy supply disruptions, influencing market expectations and causing overreactions to food and energy shortages. This has propelled energy price inflation, subsequently driving up gas prices.

The rising energy costs have, in turn, caused additional disruptions in energy supply and perpetuated inflation, effectively creating a feedback loop that exacerbates the global food crisis. The destruction of vital infrastructure, such as the breach of the Kakhovka Dam, has also contributed to Ukraine's economic and agricultural woes. Collectively, these events have triggered a sharp increase in global food prices and have severely disrupted international supply chains, demonstrating the profound and far-reaching consequences of regional conflicts on global food security and economic stability.

Figure 23 Causal loop diagram describing the cascading impacts of the Russian invasion of Ukraine.



Source: *Poljansek, et al. 2024*

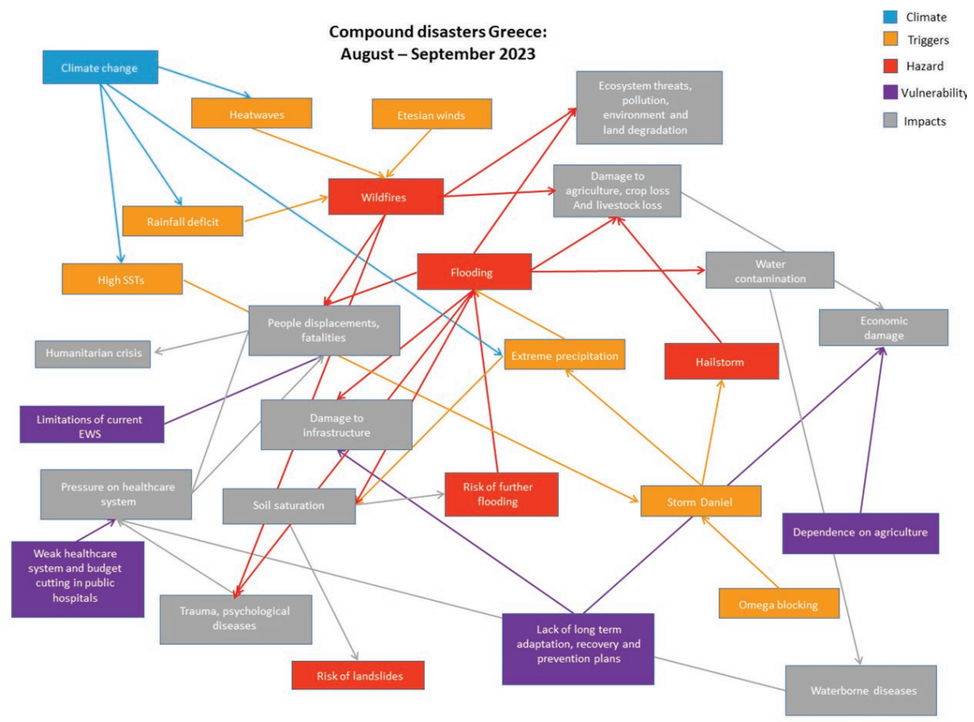
4.1.2. Causal Loop diagram for the compound disasters that hit Greece between August and September

In 2023, Greece experienced a compound disaster **Figure 24** that that unfolded in two phases. A severe drought and heatwave persisted through August, culminating in devastating wildfires in East Macedonia and Thrace, which destroyed vast areas of land, claimed lives, and damaged national parks. However, the situation took a dramatic turn in September, as Storm Daniel brought catastrophic flooding to the region of Thessaly. The storm's historic rainfall caused widespread destruction, submerging villages, destroying agricultural land and livestock, and severely impacting the country's agricultural sector (Baruth, B. et al. 2023).

High sea surface temperatures (SSTs), a consequence of global warming, contributed to Storm Daniel's intensity and the exceptional rainfall conditions (Argüeso, et al., 2024, Qiu, et al., 2023). This deluge caused major flooding, particularly in Thessaly, where it inflicted widespread agricultural damage, impacted livestock farming, and led to casualties. The relentless rainfall led to the flooding of Thessaly, which devastated cotton, corn, tomato, and apple crops, severely reducing agricultural production. Beyond the immediate agricultural impact, the floodwaters damaged homes, roads, and caused displacement of residents, challenging local authorities and escalating the economic toll. Public perception of insecurity soared as both fires and floods caused trauma and distress among the population. The environmental and economic damage was palpable, making the climate crisis a tangible and personal experience for many, and stoking fear and calls for action. Accurate forecasting and early warning systems became vital to prevent adverse effects of extreme weather and to mitigate community damage from atmospheric phenomena.

The compound disaster highlighted the urgent need for disaster preparedness and climate resilience measures to contain, respond, adapt, and ultimately to prevent damage from future hazards. Emergency preparedness and response measures are crucial in preventing disease outbreaks, while detailed crop and livestock loss assessments aided in effective flood management. As Greece continues to recover from the double blow of wildfires and flooding, proactive climate change adaptation plans, and early warning systems are essential to reduce the unpreparedness for such co-concurrent extreme events in the future.

Figure 24 Causal loop diagram describing the compound flood and wildfires occurred in Greece on the Summer 2023.



Source: Poljansek, et al. 2024

4.2. Multi-hazard exposure analysis

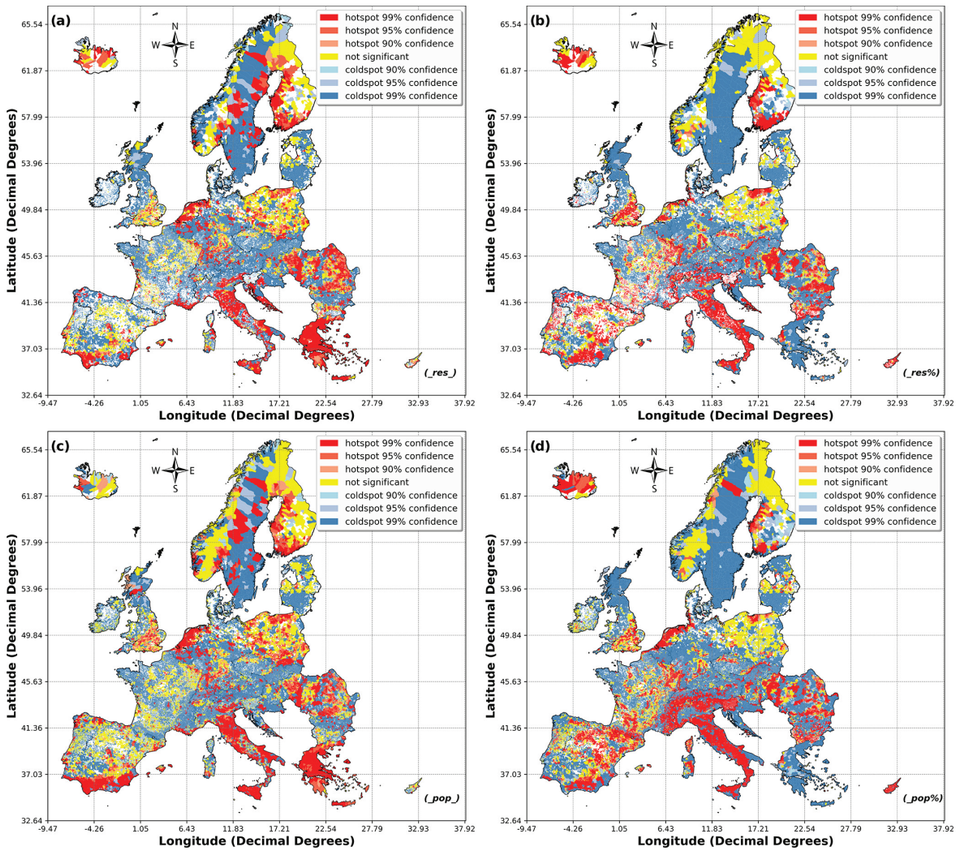
Multi-hazard exposure analysis identifies regions or assets simultaneously exposed to multiple hazards, such as earthquakes, floods, and wildfires. Understanding this overlapping exposure helps prioritise areas with higher compounded risks for targeted interventions. Many hazards are interconnected, where one can trigger or exacerbate another (e.g., earthquakes causing dam failures, leading to floods). Multi-hazard exposure analysis captures these dynamics, enabling planning that accounts for cascading effects.

Many hazards are interconnected, where one can trigger or exacerbate another (e.g., earthquakes causing dam failures, leading to floods). Multi-hazard exposure analysis captures these dynamics, enabling planning that accounts for cascading effects.

In a recent study published by the DRMKC (Antofie et al., 2025): leveraging hazard and exposure data available on the Risk Data Hub (RDH) Platform, a new methodology has been proposed to identify regions with multi-hazard exposure at the pan-European level (EU27+UK). The proposed methodology allows for the detection of the regions (LAUs) exposed to multi-hazards as function of the typology of the assets (e.g., population, residential built-up), directly revealing specific asset-threat relationships. This is important for the identification of the disaster risk management pathways in multi-hazard assessment.

The study reveals that **21.4% of European Local Administrative Units (LAUs)** are exposed to multiple natural hazards, affecting approximately **87 million people (18.8% of the European population)**. Hazard types include floods, landslides, wildfires, coastal inundation, earthquakes, and subsidence (**Figure 25**)

Figure 25 Regions (LAUs) exposed to multi-hazards.
These are identified by the meta-analysis performed on a). absolute population exposure, b.) relative (%) population exposure, c.) absolute residential built-up exposure and d.) relative (%) residential built-up exposure.



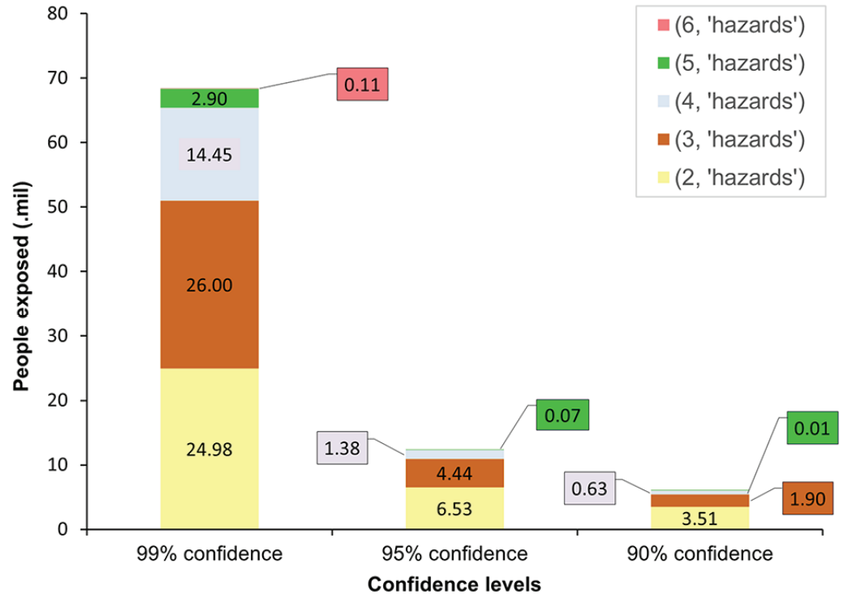
Source: Antofie et al. 2025

Key findings highlight the socio-economic dimension as a major determinant of spatial variability and risk potential at the Local Administrative Unit (LAU) level:

1. Almost half of the population is exposed to more than three hazards (**Figure 26**)

   Most of these regions are found in France (6956), Italy (4627), Slovenia (3802), Bulgaria (1876), Spain (1779), Germany and Romania (around 1000 each). Approximately a quarter of the population exposed to multi-hazards resides in Italy, with 21.4 million individuals affected.

Figure 26 Population exposed to multi-hazards by confidence interval and number of hazards.

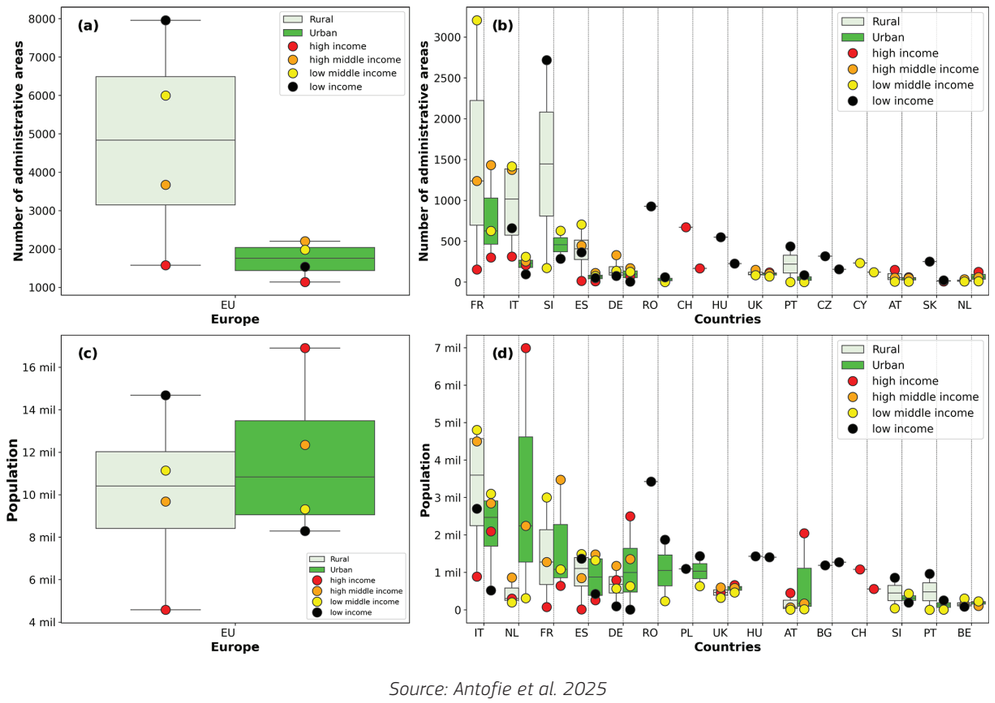


Source: Antofie et al. 2025

2. Economic and population density factors significantly influence risk profiles. The proposed methodology effectively identifies shifts in population exposure to multi-hazards by incorporating socioeconomic factors. A risk gradient emerges, increasing from low to high-middle-income countries before decreasing. Urban areas are particularly vulnerable, as shown in **Figure 27** Approximately 36% of Local Administrative Units (LAUs) with populations exposed to multi-hazards are low-income regions, and together with low-middle-income regions, they account for 67% of such LAUs. Although high-income regions represent only 10% of LAUs, and high-middle-income regions 23%, these groups comprise around 50% (43.4 million) of the population exposed to multi-hazards in Europe
3. The exposure to multi-hazard risks in both urban and rural areas is high in both cases, indicating a nearly even distribution of risk across these contrasting environments. Urban centers, home to 54% of the at-risk population (46.8 million people), experience heightened risks due to increased population density. Conversely, 46% of the population facing these risks (40.1 million people) live in rural areas. This balanced exposure highlights the need for implementing disaster risk reduction and risk prevention measures that are specifically designed to address the unique characteristics of each setting, ensuring both urban and rural communities are equally protected.

Figure 27 provides a breakdown of population exposure, showing the impacts on urban and rural areas categorised by income levels.

Figure 27 Number of administrative areas (LAUs) with population exposed to multi-hazards by income level and urbanisation level.
(a. – Europe wide, b. - the 15 highest ranked countries) (upper part); Population exposed to multi-hazards by income level and urbanisation level (c. – Europe wide, d. - the 15 highest ranked countries) (lower part).



Source: Antofie et al. 2025

The methodology was validated using historical data on fatalities and disaster events available within the RDH, showing a strong correlation (r = 0.59) between identified multi-hazard hotspots and past disaster impacts.

By pinpointing LAUs exposed to multi-hazards, this study addresses two major challenges in multi-hazard research:

1. **Identifying regions vulnerable to multi-hazards**
2. **Quantifying multi-hazard exposure.**

To refine this framework, future research will incorporate vulnerability assessments and explore the interrelations between multiple hazards. The JRC is currently exploring an approach for incorporating the Vulnerability Framework[29] (Sibilia et al. 2024) developed in the context of the Risk Data Hub for assessing multi-hazard impacts. This approach will not only broaden our view of the risks posed by individual hazards but will also enable us to grasp the compounded effects arising from the interaction of various hazards. Understanding vulnerability, therefore, serves as a key to unlocking a multi-dimensional perspective on multi-hazard risk, ultimately leading to more informed and effective risk management strategies.

29 Vulnerability Framework https://www.sciencedirect.com/science/article/pii/S2212420924006472

Policy recommendations

- **Support Rural Risk Reduction:** Implement disaster risk reduction strategies in rural areas, which are also significantly affected by multi-hazards. This includes improving early warning systems to reach rural communities, enhancing local capacity for emergency response, and ensuring that rural development projects are risk-informed.
- **Strengthen Urban Resilience:** As urban areas are identified as having high exposure to multi-hazards, policies should focus on: i) strengthening urban infrastructure, implementing stringent building codes, and enhancing emergency services to increase resilience in highly urbanised regions exposed to multi-types of hazards ii) and integrating urban planning with multi-hazard assessments to mitigate risks associated with dense populations and expanding functional urban areas.
- **Promote Cross-Border Collaboration**: As all the baseline datasets used for analysis are available on the Risk Data Hub, it is encouraged to use the RDH to foster cross-border collaboration in risk assessment and management, as multi-hazard risks do not respect political boundaries. Shared data and methodologies can lead to more effective regional DRM strategies.
- **Encourage the standardisation of hazard assessment** approaches across EU MS to ensure consistency and comparability.
- **Incorporate Vulnerability and hazard interrelations into Future Assessments**: ssuch improvement in methodology would provide a more comprehensive understanding of risks and inform more effective prevention and response strategies.

Conclusions and Recommendations

The European risk landscape is complex and multifaceted, involving a wide range of risks including cross-border, emerging, climate-related, and high-impact, low-probability (HILP) risks. These risks require integrated and proactive management strategies. Understanding the interconnected nature of these risks is crucial, as they often amplify one another, leading to compounded impacts that can cascade across sectors and regions.

JRC experts analysed this interconnectedness and identified the systemic nature of the risks, and which sectors that are potentially more vulnerable to the resulting cascading effects. The quantification of all risk using unified framework that accounts for interconnections is essential, as it facilitates a thorough comprehension of the relationships between various risk types and cascading impacts. This comprehensive approach helps in identifying vulnerabilities and resilience gaps, enabling more targeted interventions.

The findings reveal that the primary risk drivers across the 47 hazards analysed include **geopolitical instability**, which is linked to **21 hazards, weak governance (19 hazards), climate change (17 hazards), urbanisation (17 hazards), environmental degradation (14 hazards)**, and **technological developments (10 hazards)**. These drivers not only exacerbate existing risks but also create new vulnerabilities, necessitating adaptive risk management strategies that are responsive to evolving threats.

Consequences may be varied; however, several recurring patterns of potential impacts demonstrate that different risks often lead to similar disruptions:

The analysis identified the number of risks affecting different impact sectors. **The most frequently impacted sector is 'Economic Disruption,' with nearly 40 risks associated. 'Human Health' follows closely, also nearing 40 risks. 'Essential Services Disruption' and 'Infrastructure/Property Damage' are impacted by approximately 30 risks each. 'Environmental Degradation' and 'Social and Political Instability' show slightly fewer cases, around 25**. Other critical sectors such as 'Food and Water Security' and 'Supply Chain Disruption' are affected by about 20 risks. 'Psychological and Social Well-being' and 'Displacement and Migration' fall within the 10-15 range. Less frequently impacted sectors include 'Public Health System Stress,' 'Governance and Institutional Challenges,' and 'Technological Disruption,' each influenced by fewer than 10 risks. The least affected areas are 'Education and Skill Development' and 'Cultural and Heritage Loss,' each with only a few associated risks. These interconnected impacts highlight the importance of cross-sectoral strategies that address multiple risks concurrently, optimizing resource allocation and enhancing overall resilience. These consequences arise from natural hazards (floods, droughts, earthquakes), technological and cyber threats (AI risks, cybersecurity, Natech), geopolitical and societal hazards (armed conflicts, food insecurity migration), and environmental hazards (air and marine pollution).

The report highlights operational gaps in areas like cross-border cooperation and data sharing, policy gaps in legal frameworks, and research gaps in understanding complex risks. Bridging these gaps requires enhanced collaboration among EU member states and stakeholders, fostering an environment of shared learning and innovation.

Common gaps across risks include:

Research gaps: methodology limitations, data availability and accuracy issues, and insufficient scientific literature are common research gaps across various risks.

Policy gaps: a lack of standardised guidelines, inadequate funding and resources, and insufficient international cooperation are common policy gaps across risks.

Operational gaps: limited capacity and resources, inadequate data collection and monitoring, and challenges in implementing practices are common operational gaps across risks.

Key areas for improvement include addressing gaps in data availability and accuracy, strengthening international cooperation, establishing robust regulatory frameworks is necessary for managing technological risks and misinformation, enhancing public awareness and education can improve resilience against various risks.

Addressing Earth Systems Tipping Points requires a revised approach to risk assessment, including anticipatory governance and foresight methods. Current frameworks may not adequately capture the long-term and irreversible impacts of ESTPs. Incorporating foresight tools can help policymakers anticipate potential tipping points and prepare adaptive responses that minimize adverse outcomes.

Effective risk management requires an all-hazards and all-of-society approach, recognising that risk management is a collective responsibility involving all stakeholders. This approach emphasises the need for coordinated and collaborative responses to risks, sharing information, resources, and expertise across sectors and borders. By adopting this approach, the interconnected nature of risks and their potential cascading effects can be better addressed. This collective effort ensures that diverse perspectives and expertise are harnessed to build resilient systems capable of adapting to rapid changes and unforeseen challenges.

General conclusions and cross-cutting recommendations

Europe is facing an increasingly complex and interconnected risk landscape, shaped by a range of emerging threats, systemic vulnerabilities, and transboundary hazards. In this context, there is an urgent need to strengthen **systemic, forward-looking risk governance across the European Union**. While the Union Civil Protection Mechanism (UCPM) provides a vital framework for coordinating prevention, preparedness and response activities, its potential to serve as a central hub for risk governance can only be fully realised if it is more effectively linked with key sectoral policies-particularly in areas such as climate change, health, critical infrastructure, and security.

At present, persistent gaps in risk knowledge, coordination mechanisms, and data infrastructure are undermining Europe's collective capacity to anticipate, prevent and manage future crises. These challenges are compounded by the growing impact of climate change, the increasing frequency of high-impact, low-probability events, and the evolving nature of technological and hybrid threats.

The analysis of past and future losses also shows a pronounced upward trend in projected impacts across nearly all risk categories, with indirect impacts-such as societal disruption and economic ripple effects—expected to significantly exceed direct losses in the coming years. This underscores the urgency of adapting current governance models to address not only traditional hazards, but also systemic and intangible risks that may manifest across borders and sectors.

Moreover, some risk categories with historically limited loss data-such as cyber incidents, artificial intelligence misuse, and space weather-are now identified as having potentially high future impacts. This points to a critical need for anticipatory planning and investment in risks that are currently underrepresented in preparedness strategies. Incorporating cutting-edge technologies and data analytics can enhance the capacity for early detection and rapid response to these emerging threats.

Bridging these gaps requires a strategic shift towards a more integrated, cross-sectoral, and participatory approach to disaster risk management.

To address these challenges and advance a more coherent risk governance ecosystem, several **strategic recommendations** are proposed for decision makers and for the research and practitioner communities:

Recommendations for decision makers

Legislative integration is essential. Stronger legal interlinkages between the UCPM and other key

EU policy frameworks-such as the Critical Entities Resilience Directive (CER), the NIS2 Directive, and the EU Climate Law-should be established to support more seamless coordination and unified risk assessment practices. This integration will facilitate more efficient resource allocation and policy implementation, ensuring that diverse risks are addressed comprehensively.

The EU and Member States should adopt a **risk-informed investment approach** across relevant funding instruments. Disaster Risk Financing and Insurance (DRFI) strategies can serve as a lever to prioritise preventive actions and resilience-building, shifting from reactive to proactive modes of governance. This investment approach should be informed not only by historical loss patterns, but also by projections of future systemic and indirect impacts, as revealed in the impact trend analyses 3.1.4. Health impacts linked to climate change—such as extreme heat, vector- and water-borne diseases, and air pollution—must be integrated into these risk-informed investment strategies. This includes prioritising adaptation measures like heat-health action plans, surveillance of climate-sensitive diseases, and the strengthening of health system resilience, in line with the EU Adaptation Strategy and the Climate and Health Observatory. Such an approach will enhance the EU's capacity to withstand and recover from diverse disruptions, safeguarding economic stability and societal well-being.

A **whole-of-society approach** must be encouraged. Inclusive risk governance requires the meaningful engagement of public institutions, the private sector, civil society organisations, and local communities in the co-design and implementation of disaster resilience strategies. This collective engagement ensures that diverse perspectives and local knowledge are integrated into risk management processes, fostering community ownership and trust.

Recommendations for researchers and practitioners

There is a need to **co-create fit-for-purpose tools** that translate scientific knowledge into actionable insights for decision-makers. This includes the development of user-friendly decision dashboards, predictive analytics, and multi-hazard early-warning systems that can support real-time planning and crisis anticipation. These tools should be adaptable to various contexts and accessible to a broad range of stakeholders, facilitating informed decision-making and timely interventions.

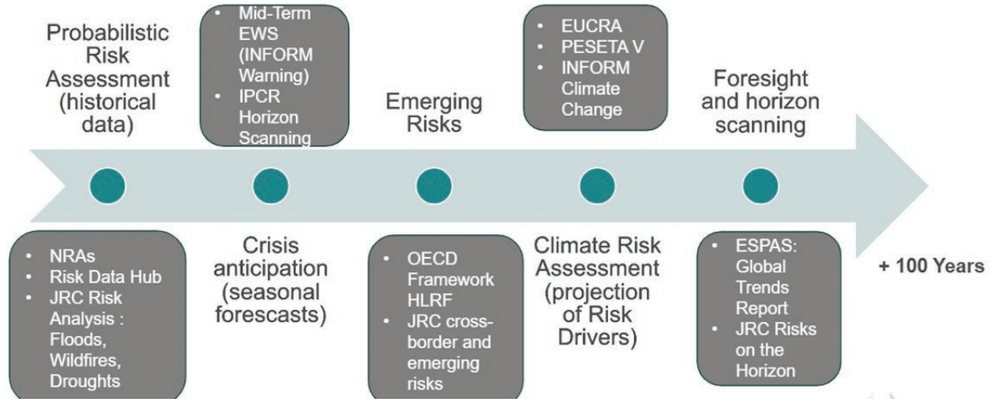
Standardisation of methodologies is critical to enable comparability across Member States and to enhance collective learning. This should be supported by coordinated efforts to share good practices, foster interoperability, and ensure that data and tools are accessible to a broad range of actors. Harmonized method, model and data standards will promote consistency in risk assessments and facilitate cross-border collaboration, optimizing the effectiveness of risk management efforts.

Research and standardisation efforts should place greater emphasis on **emerging and systemic risks**, including those related to artificial intelligence, hybrid threats, and climate tipping points, incorporating probability assessments to determine the likelihood and potential impact of these risks. Developing modular, adaptive, and scalable risk assessment approaches will be key to responding to the dynamic nature of these threats. Such approaches will enable stakeholders to anticipate and adapt to rapidly changing risk landscapes, enhancing resilience in the face of uncertainty.

Cross-cutting recommendations

Finally, a cross-cutting recommendation, to effectively manage this diversity of risks, it is essential to distinguish between the different time horizons and analytical approaches used in risk assessment. As illustrated in the comparative framework (**Figure 26**) of risk analysis timeframes, risk studies vary significantly—from probabilistic assessments based on historical data, used for well-known natural hazards like floods and wildfires, to foresight and horizon scanning that look over 100 years ahead to anticipate geopolitical, technological, and environmental transformations. Tools such as seasonal forecasts (e.g., for crisis anticipation), mid-term early warning systems, and emerging risk mapping (like EUCRA or the JRC's cross-border risk analysis) all play different but complementary roles. Integrating these diverse methodologies ensures a comprehensive understanding of risks across temporal dimensions, allowing for informed decision-making that balances immediate needs with long-term resilience. This diversity reflects the complex nature of risk governance today, where no single method or timeframe is sufficient. For a truly comprehensive EU-wide risk assessment, it is therefore crucial to consider not only the variety of risks and their potential cascading impacts on vital societal functions—such as health, infrastructure, economy, and environment—but also the temporal dimension of those risks, ensuring that short-term hazards and long-term threats are equally addressed. **Recognising these distinctions allows policymakers and practitioners to better align their strategies—whether focused on immediate crisis response or long-term systemic resilience.**

Figure 28 Comparative timeframe of risk analysis approaches in Disaster Risk Management



Source: Authors' elaboration.

In developing a comprehensive EU-wide threat and risk assessment, it is essential to build upon existing tools and frameworks, such as:

- The Risk Data Hub, The RDH can support the development of an EU-wide risk assessment by aggregating and analysing data on exposure, vulnerability to multiple types of hazards from national and regional levels, providing a comprehensive overview of the risk landscape across the EU. It can also curate damage and loss data from various sources. This can help improve the understanding of the impacts of disasters and support the development of more accurate risk models and loss estimates.
- The framework for Mid-term Early Warning for anticipating crisis 6 months ahead (Poljansek et al. 2024), which provides a solid foundation for anticipating disasters and crises within a 6-month window. The methodology employed a quarterly expert-based assessment approach, utilizing "signal templates" to identify and capture significant potential crisis signals and their anticipated impacts. These signal templates provided a standardized framework for experts to share their insights, facilitating the efficient uptake of critical information by decision-makers. Over time, the compiled data was used to develop causal loops, which distilled key findings, visualized the relationships between hazards and impacts, and exposed the compounding effects of interconnected risks. Additionally, the causal loops help pinpoint opportunities for proactive and anticipatory actions, that are enablers for informed and timely decision-making process. The development of such mid-term early warning frameworks is also aligned with the objectives of multi-hazard risk assessment frameworks, such as those developed in the context of European Funded projects as Myriad and Paratus.

Additionally, the report on cross-border and emerging risks (Corbane et al. 2024), the climate and conflict trend analysis of the Joint Communication on Climate and Security (Whitaker, E. et al. 2025), the Risks on the Horizon report of the JRC for foresight (Muench et al. 2024), and the Strategic Foresight Report 2025 (EU 27) offer valuable insights and methodologies that can be leveraged to enhance the EU's risk assessment capabilities. In conclusion, strengthening Europe's resilience requires a

bold, coordinated, and future-oriented agenda for risk governance—one that brings together science, policy, and society in a shared effort to protect people, ecosystems, and critical systems from the evolving risks of the 21st century.

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BIPAR European Federation of Insurance and Financial Intermediaries; Insurance Europ; World Bank; BEUC Bureau Europ en des Consommateurs/The European Consumer Organisation; FERMA Federation of European Risk Management Associations; EIOPA European Insurance and Occupational Pensions Authority; UNEP FI United Nations Environment Programme Finance Initiative; EU-CoM EU-Covenant of Mayors; UNDRR; AAE Actuarial Association of Europe; SMEunited; UIPI Union Internationale de la Propri t Immobili re/International Union of Property Owners; PEIF Pan European Insurance Forum; EEA; CRO ForumChief Risk Officers Forum; RAB Reinsurance Advisory Board; AMICE Association des assureurs mutuels et coop ratifs en Europe/ Association of Mutual Insurers and Insurance Cooperatives in Europe, 2025, Climate resilience dialogue, FINAL REPORT. (2025)

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List of abbreviations and definitions

Abbreviations	Definitions
AI	Artificial Intelligence
AMOC	Atlantic Meridional Overturning Circulation
AMR	Antimicrobial Resistance
C3S	Copernicus Climate Change Service
CB	Cross-border
CCA	Climate Change Adaptation
CCAFS	Climate Change, Agriculture and Food Security
CEAR	Collateral Exposure At Risk
CEMS	Copernicus Emergency Management Service
CEPOL	European Union Agency for Law Enforcement Training
CER	Critical entities resilience
CLD	Causal Loop Diagrams
COPD	Chronic Obstructive Pulmonary Disease
CoR	European Committee of the Regions
CP	Civil Protection
CRA	Climate Risk Assessment
DG	Directorate General
DG CLIMA	Directorate-General for Climate Action
DG ECFIN	Directorate-General for Economic and Financial Affairs
DG ECHO	Directorate-General for Civil Protection and Humanitarian Aid Operations Organisation
DG ENV	Directorate-General for Environment
DG FISMA	Directorate-General for Financial Stability, Financial Services and Capital Markets Union
DG HOME	Directorate-General for Migration and Home Affairs
DG REGIO	Directorate-General for Regional and Urban Policy
DG RTD	Directorate-General for Research and Innovation
DRF	Disaster Risk Financing
DRFI	Disaster Risk Financing and Insurance
DRG	Disaster Resilience Goal
DRM	Disaster Risk Management
DRMKC	Disaster Risk Management Knowledge Centre

DRR . . . . . Disaster Risk Reduction
EC . . . . . European Commission
ECDC . . . . . European Centre for Disease Prevention and Control
ECMWF . . . . . uropean Centre for Medium-Range Weather Forecasts
EEA . . . . . European Environment Agency
EEAS . . . . . European External Action Service
EFSA . . . . . European Food Safety Authority
EIB . . . . . European Investment Bank
EIOPA . . . . . European Insurance and Occupational Pensions Authority
ENSO . . . . . El Niño–Southern Oscillation
ENTSO-E . . . . . European Network of Transmission System Operators for Electricity
EP . . . . . European Parliament
ERCC . . . . . Emergency Response Coordination Centre
ERCC SLA . . . . . Emergency Response Coordination Centre Standardised Liaison Arrangement
ESA . . . . . European Space Agency
ESM . . . . . Earth System Model
ESOTC . . . . . European State of the Climate
ESPAS . . . . . European Strategy and Policy Analysis System
ESTP . . . . . Earth System Tipping Point
ETC CE . . . . . European Topic Centre on Climate Change Adaptation and the Environment
EU . . . . . European Union
EU INTPA . . . . . European Commission Directorate-General for International Partnerships
EU-OSHA . . . . . European Agency for Safety and Health at Work
EUCRA . . . . . European Climate Risk Assessment
EUDIS . . . . . European Defence Industry Strategy
EUSF . . . . . EU Solidarity Fund
EUSSSD . . . . . EU Space Strategy for Security and Defence
FIMI . . . . . Foreign Interference and Manipulation of Information
FISMA . . . . . Financial Stability, Financial Services and Capital Markets Union
HERA . . . . . Health Emergency Preparedness and Response Authority
HILP . . . . . High Impact, Low Probability
HIPs . . . . . Hazard Information Profiles
HORIZON EU . . . . . Horizon Europe – EU Research and Innovation programme
HR/VP . . . . . High Representative of the Union for Foreign Affairs and Security Policy / Vice-President of the European Commission
ICRC . . . . . International Committee of the Red Cross
IFRC . . . . . International Federation of Red Cross and Red Crescent Societies
IOM . . . . . International Organization for Migration
IoT . . . . . Internet of Things
IPBES . . . . . Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC . . . . . Intergovernmental Panel on Climate Change
IRGC . . . . . International Risk Governance Council
JRC . . . . . Joint Research Centre
JRC CDP . . . . . Joint Research Centre Collaborative Doctoral Partnership

LAU . . . . . Local Administrative Unit
LRA . . . . . Local and Regional Authorities
MS . . . . . Member States
NASA . . . . . National Aeronautics and Space Administration
NATECH . . . . . Natural Hazard Triggering Technological Disasters
NATO . . . . . North Atlantic Treaty Organization
NBS . . . . . Nature-Based Solutions
NCD . . . . . Non-Communicable Disease
NEAR . . . . . Normalised Exposure At Risk
NECP . . . . . National Energy and Climate plans
NGFS . . . . . Network for Greening the Financial System
OECD . . . . . Organisation for Economic Co-operation and Development
PEAR . . . . . Potential Exposure At Risk
PESCO . . . . . Permanent Structured Cooperation
PPR . . . . . Prevention, Preparedness and Response
PS . . . . . Participating States
RDH . . . . . Risk Data Hub
SAR . . . . . Search and Rescue
SARS . . . . . Severe Acute Respiratory Syndrome
SDGs . . . . . Sustainable Development Goals
SST . . . . . Sea Surface Temperature
UCPM . . . . . Union Civil Protection Mechanism
UCPM Art. 6 . . . . . Article 6 of the Union Civil Protection Mechanism legislation
UNDRR . . . . . United Nations Office for Disaster Risk Reduction
UNICEF . . . . . United Nations Children's Fund
UNECE . . . . . United Nations Economic Commission for Europe
UNOCHA . . . . . United Nations Office for the Coordination of Humanitarian Affairs
UNOPS . . . . . United Nations Office for Project Services
UNSC . . . . . United Nations Security Council
WB . . . . . World Bank
WHO Europe . . . . . World Health Organization Regional Office for Europe
WMO . . . . . World Meteorological Organisation
WMO-GFCS . . . . . World Meteorological Organization – Global Framework for Climate Services
WUI . . . . . Wildland-Urban Interface

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Reports category Disaster risk Management

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	MAIN CONCLUSIONS	Reporting Frequency
DISASTER RISK MANAGEMENT								
1	Mid-term Early Warning anticipating crisis 6 months ahead	JRC	2024	On advancing towards integrated mid-term early warning system that will aim at anticipating disasters and crises within a 6-month window. Ability to detect crisis a few months in advance that are likely to have major cross-sectorial impact is on high demand because it provides another opportunity for the transition from reactive to proactive crisis risk management strategies.	To understand which expert groups in JRC have skills to provide signals for crisis within this time window, collect knowledge within the same multi-hazard framework and identify challenges of midterm early warning to define the way forward. This report outlines the approach adopted for achieving these objectives by harnessing existing forecasts and monitoring tools from JRC units specializing in an array of different hazards or their already manifested adverse impacts, such as: river flooding, armed conflicts, droughts, tropical storms, food insecurity, health, nuclear threats, and migration.	Uses a signal template challenge, where expert groups from various JRC teams were tasked with filling out a template every three months to capture major signals indicating potential crises that may arise within the next three to six months, as well as their forecasted impacts. The report also applies causal loop diagrams to support integrated mid-term early warning system development, which helps to visualize the complex interactions between various hazards, vulnerability drivers, and their impacts	The collaborative effort to integrate data, pool expertise, and leverage resources from various JRC teams has shown promise in detecting (multi-hazard) crises early, within a four to six-month timeframe. The report concludes that a comprehensive and multifaceted approach to crisis prediction is necessary, and that evaluating the effectiveness of these strategies is important. The report also highlights the need for ongoing efforts in knowledge collection and validation, ensuring a multi-hazard early warning system where timely detection for effective mitigation measures is crucial	n.a.
2	Evaluation Study of Definitions, **Gaps** and **Costs of Response Capacities for the Union Civil Protection Mechanism**	DG-ECHO	2024	Evidence on the appropriateness of the currently available response capacities	To support the European Commission to further develop disaster response capacities under the UCPM and to inform the creation of a dedicated EU-level response in specific	Desk research, expert assessment		yes (every few years); next in 2025
3	Natural disasters: anticipatory governance and disaster risk management from a local and regional perspective	European Committee of the Regions (CoR)	2024	Natural disasters, anticipatory governance, and disaster risk management in the European Union	The study aims to map and analyse tools to develop and improve the anticipatory governance approach to disasters, disaster risk management, and climate adaptation by Local and Regional Authorities (LRAs) across the EU	The study uses a desk research approach, analysing existing literature and policies related to disaster risk management and climate adaptation in the EU. It also examines the role of LRAs in fostering climate change adaptation and the benefits of local adaptation measures	All EU regions are vulnerable to climate change, and that LRAs play a crucial role in disaster risk management and climate adaptation. It also highlights the importance of anticipatory governance, strategic foresight, and inclusive decision-making processes in reducing the risks associated with natural disasters	n.a.

4	(Prevention Progress Report 2024) **on progress on implementation of article 6** of the Union Civil Protection Mechanism (Decision No 1313/2013/EU)	DG-ECHO	2024	Implementation of Article 6 of the UCPM and disaster risk management in Europe	Present progress made in implementing Article 6 of the UCPM, which focuses on risk management and disaster prevention, and to provide recommendations for further implementation taking into account the increasing risks and challenges posed by climate change, global security threats, and other hazards.	Analysis o DRM summary reports provided by EU MS/PS between 2020 and September 2022. Review of the effectiveness of the UCPM in supporting and complementing MS	There is a need to further strengthen disaster risk management in Europe, particularly in light of increasing climate-related risks. The Union disaster resilience goals, adopted in February 2023, provide a common baseline for managing disaster risks with multi-country, transboundary impacts. There is a need to improve the systematic collection of disaster loss data and to make this data available through the Risk Data Hub. The report highlights the importance of cross-sectoral disaster risk management, mainstreaming disaster risk management into other policies, and investing in disaster risk management. The report also emphasizes the need for a whole-of-society approach to disaster risk management, involving all stakeholders, including public institutions, academic and research bodies, the private sector, civil society, and communities	yes (every few years) based on the NRA submitted by MS/PS every 3 years

5	Strengthening the **resilience of EU border** regions	DG-REGIO	2024	Gap analysis of EU border regions, specifically identifying risks, vulnerabilities, and gaps in crisis management tools and governance readiness	Identifying gaps and discrepancies in risk assessment; Mapping risks and crisis management tools; Improving data availability and quality; support drm	The methodology/approach used in the study involves a combination of qualitative and quantitative methods, including: • A review of existing literature and reports on disaster risk management in EU border regions • Interviews with experts and stakeholders • Analysis of national risk assessments and emergency plans • GIS-based mapping of risks and vulnerabilities • Development of analytical tables and infographics to visualize risk assessments	• There are significant gaps in disaster risk management in EU border regions, particularly in terms of cross-border cooperation and coordination • Member States have varying levels of governance readiness and capabilities to address risks, with some countries showing stronger capabilities than others • There is a need for more comprehensive and harmonized risk assessments, as well as improved data sharing and information exchange between countries • Cross-border agreements and tools are essential for effective disaster risk management, but there are significant gaps in these areas	n.a.

6	**JRC Cross-border and emerging risks 2024**	JRC	2024	Analysis of complex disaster risks that transcend national borders and future challenges to EU	It outlines the State of the knowledge, tools, methods and strategies for risk assessment, highlighting the necessity for harmonized frameworks for the identification, assessment, and evaluation of emerging risks.	List of cross border and emerging list reporting for each one is presented a summary of methods, tools, and strategies for risk assessment. Gaps and needs for harmonisation.	Risk assessment methodologies need refinement need for a systemic multi-hazard and multi-risk framework to address the co-occurrence of multiple hazards.Data availability and quality are crucial. Emerging risks require attention. Holistic approach to risk assessment. Research, science, and data are key	probably annual

7	Recommendations for **National Risk Assessment for Disaster Risk Management** in EU	JRC	2021	To support the use of the new Reporting Guidelines on Disaster Risk Management, Art. 6(1) of Decision No.1313/2013/EU-2019/C 428/07	To create a risk governance framework that supports effective risk assessment and informs disaster risk management planning and implementation, from prevention to recovery	Literature review. Expert analysis. Case study. Policy analysis	NRA is essential for evidence-based policy making and should be tailored to the national context to implement integrated disaster risk management (DRM). RMCA is necessary to set up a risk governance structure and facilitate policy cycle from NRA to DRM planning and implementation. High-quality data and availability is essential for accurate risk assessment Risk assessment models need to be developed and improved to reduce uncertainties and better understand complex risks. Understanding of risk drivers is crucial how they affect the level of risk to develop effective risk reduction measures. A common understanding of risks and harmonisation of risk metrics is necessary to compare risks across hazards, regions, and assets. Climate change adaptation strategies should be integrated: Climate change adaptation strategies should be integrated into DRM planning to enhance resilience against disaster risks	n.a.

8	Overview of natural and man-made disaster risks the European Union may face	DG-ECHO	2020	Overview of the natural and man made disasters to identify and examine trends in the ever-evolving disaster risk landscape.	To capture the trends in the ever-evolving disaster risk landscape, discuss the major drivers shaping it, and assess the implications of developments in disaster risks for risk management Improve awareness of disaster risk to inform risk management policies in Europe; Foster a sound understanding of disaster risks facing Europe s population Inform decision-making on risk management to prevent loss of life and damage.	The report draws on the latest available evidence from the Commission s cross-sectoral policy, operational and scientific work on disaster risk, as well as national disaster risk assessments sent to the Commission by the EU MS/PS of the UCPM during the 2018 reporting cycle	Europe is facing an increasing number of disaster risks. Climate change is a major driver of disaster risk, and its impacts are already being felt in Europe. Urbanization, development in hazardous areas, and unsustainable land use have put more people and wealth in harm's way. There is an important need for effective prevention, mitigation, preparedness, response, and recovery from disasters in the future. The report identifies priority areas of action, including addressing the major causes of risk, increasing cooperation across borders and sectors, investing in prevention and preparedness, and boosting the EU's collective capacity to respond to high-impact disasters.	yes (every few years), next in 2025

9	**Science for Disaster Risk Management** 2020	JRC	2020	DISASTER RISK MANAGEMENT	Provide a comprehensive and actionable guide to disaster risk management, with a focus on supporting stakeholders in reducing disaster risk and promoting resilience. study the impacts of disasters on various assets at risk, such as population, economic sectors, critical infrastructures, ecosystem services, and cultural heritage, in order to support disaster risk management, response, recovery, and prevention.	Collaborative, interdisciplinary, and adaptive approach, aimed at bringing together diverse perspectives and expertise to inform disaster risk management	Shift from short-term to long-term perspective: Focus on addressing underlying drivers of risk, rather than just responding to emergencies. Improve data collection and sharing: Consistent, comprehensive, and accessible data is needed to inform disaster risk management decisions. Foster collaboration and coordination: Collaboration among stakeholders, including governments, scientists, and the private sector, is crucial for effective disaster risk management. Address intangible impacts: Intangible impacts, such as those related to cultural heritage and ecosystem services, must be considered in disaster risk management. Strengthen capacities and partnerships: Capacities and partnerships at different levels of policy-making processes must be strengthened to improve disaster risk management.	n.a.

Reports category defence and security

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	MAIN CONCLUSIONS	Reporting Frequency
DEFENCE and SECURITY								
10	Progress Report on the implementation of the Joint Communication - **"A New Outlook on the Climate and Security Nexus"**	Council of European Union, HIGH REPRESENTATIVE OF THE UNION FOR FOREIGN AFFAIRS AND SECURITY POLICY	2025	The Joint Communication is about addressing the impact of climate change and environmental degradation on peace, security, and defence, and proposes a new outlook on the climate and security nexus, aiming to strengthen climate and environment-informed planning, decision-making, and implementation in EU external action, and to support Member States in addressing the growing challenges involved.	The report outlines the progress made in implementing the Joint Communication on the climate and security nexus. The main aims of the report are to provide an overview of the progress achieved across the four pillars of the Joint Communication and to identify areas for further action	Assessing the implementation of the 28 actions outlined in the Joint Communication, which are grouped into four pillars: evidence-based analysis and foresight, operationalizing the climate and security nexus in EU external action, ensuring a sustainable and climate-resilient European security and defence, and international cooperation	Progress has been made across all four pillars, with achievements including the establishment of the Climate Change, Environment, Security, and Defence (CCESD) training platform, the development of a climate and security trend analysis, and the integration of climate and security considerations into EU external action	n.a.
11	Report: Safer Together Strengthening Europe s Civilian and Military Preparedness and Readiness **(Niinistö Report)**	Sauli Niinistö, former President of the Republic of Finland (special Adviser to the president of EC)	2024	Enhancing the EU's preparedness and readiness to respond to future crises, and on developing a comprehensive and integrated approach to preparedness that involves all relevant actors and stakeholders	The report underlines the need for an ambitious new approach to our preparedness and readiness (specifically focusing on civilian and defence). To this end, it presents around 80 recommendations for short-term and medium to long-term actions.	Desk research, analysis, review and validation of existing information, recommendations and data through actors engagement, consultations, expert input and advices; it also draws on various relevant work strands that are already ongoing (horizontal crisis management, the implementation of the Strategic Compass, and other relevant EU strategies, initiatives, and policies across sector)	The EU needs: to adopt a robust all-hazards, whole-of-government, and whole-of-society approach to its civilian and military preparedness and readiness. to take more strategic responsibility for security in Europe and prioritize the long-term benefits of a fully prepared EU over its short-term costs. should focus on building strong relationships with other countries and working together to make each other stronger and more resilient. This will help the EU become a trusted and reliable partner in the world needs to invest more in preparedness, including in areas such as defence to ensure the procurement of crisis-relevant goods in a coordinate way, so that everyone has access to what they need without prices becoming too high.	n.a.

12	Strategic Compass 2024 for Security & Defence (Annual progress report)	EU (HR/VP for Foreign Affairs and Security Policy to the Council)	2024	Progress update on the implementation of the EU Strategic Compass, which was adopted in March 2022 to strengthen the EU's security and defence capabilities	To provide an update on the progress made by the EU in implementing the Strategic Compass and current gaps/Needs	It is a review of the EU's efforts (based on various initiatives, actions, and decisions taken by the EU and its Member States) to become a stronger and more credible security and defence actor, both within the EU and globally	EU has made significant progress but there is a need for: Increased defence spending and investment in the EU Improved cooperation and coordination among EU Member States . Strengthening the EU's defence industry and technological base Enhancing the EU's partnerships with other international organizations and countries	ANNUAL
13	Strategic Compass 2022 for Security & Defence	EU (HR/VP for Foreign Affairs and Security Policy to the Council)	2022	Strategic Compass for Security and Defence.	To guide the necessary development of the EU security and defence agenda for the next ten years, to strengthen the EU's capacity to protect its citizens, values, and interests, and to contribute to international peace and security	Based on a comprehensive analysis of the EU's security environment, threats, and challenges, as well as a review of the EU's existing security and defence policies and initiatives. The EU Threat Analysis in 2020 helped develop a common understanding of the threats and challenges that the EU will face in the near future	EU needs to take a more active stance to protect its citizens, defend its interests, project its values, and work with partners to provide security for a safer and more just world. need for the EU to invest more in its security and defence capabilities, to strengthen its partnerships with other countries and organizations, and to develop a more comprehensive and integrated approach to security and defence	n.a.

14	**Migration Preparedness and Crisis Blueprint** 2020	EC	2020	Migration Preparedness and Crisis Blueprint, which is a mechanism for preparedness and management of crises related to migration at the EU level.	To ensure a more coordinated use of the existing legislation by reinforcing and sharing common situational awareness between all actors involved, developing an early warning/ forecasting system at EU level, and supporting resilience in Member States to efficiently deal with any type of migration crisis.	Use of situational reports, early warning/ forecasting systems, and contingency planning to monitor and prepare for migration crises	It emphasizes the importance of cooperation and coordination among all actors involved, as well as the need for a structured approach to migration management and crisis response.	n.a.

Reports categories CLIMATE CHANGE, CLIMATE RISK ASSESSMENT and CLIMATE ADAPTATION.

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	3. MAIN CONCLUSIONS	Reporting Frequency
CLIMATE CHANGE, CLIMATE RISK ASSESSMENT and CLIMATE ADAPTATION								
15	**Earth System Tipping Points are a threat to Europe**	JRC	2025	Earth System Tipping Points (ESTP) and their threat to Europe	The summary highlights the current state of knowledge on Earth tipping points, including the potential risks and consequences of exceeding these thresholds, and the need for further research and investment in this area to better understand and mitigate these risks.	The approach involves the use of biophysical modelling, Earth Observations, and socio-economic modelling to characterize ESTP-related risks and to identify hotspots of action . The document also highlights the need for a multidisciplinary approach, involving scientists, policymakers, and stakeholders from various domains	4. The main conclusions are that ESTP pose a significant threat to Europe, and that urgent anticipatory governance is needed to prepare for the potential impacts of ESTP. The document also concludes that the economic impacts of ESTP are underestimated and that enhanced financial mechanisms are needed to support climate adaptation and preparedness efforts	n.a.
16	European Climate Risk Assessment (**EUCRA**)	EEA, EC (Dgs CLIMA, JRC; and C3S)	2024	Identifies 36 climate risks with potentially severe consequences across Europe	Climate risks affecting energy, food security, ecosystems, infrastructure, water resources, financial stability, health	Risk assessment on major risks; quantitative and qualitative knowledge sources on climate change, associated impacts, and adaptation. risk storylines, identifying and assessing major climate risks	5. Europe is warming faster than any other continent, facing critical climate risks that threaten its security, ecosystems, and people's health. [1] Key urgent actions include: 6. Reducing greenhouse gas emissions 7. Implementing strong adaptation policies 8. Protecting ecosystems 9. Safeguarding against heat, floods, and wildfires 10. Securing European solidarity mechanisms [1] 11. The EU and its Member States must work together to address these risks, and there is a need for improved understanding of climate risks through research and development	n.a.

17	**Preparing society for climate risks in Europe** – lessons and inspiration from **Climate-ADAPT case studies**	EEA	2024	Assessing the impacts of climate change and the effectiveness of existing adaptation measures in Europe	1. Assess the effectiveness of existing adaptation measures in Europe. 2. Identify gaps and areas for improvement in climate change adaptation. 3. Provide insights into the impacts of climate change on European societies. 4. Support the development of effective climate change adaptation policies and strategies.	1. Literature review: A comprehensive review of existing research and reports on climate change impacts and adaptation measures in Europe. 2. Case studies: In-depth analysis of selected case studies to illustrate the impacts of climate change and the effectiveness of adaptation measures. 3. Stakeholder engagement: Consultations with stakeholders, including policymakers, scientists, and practitioners, to gather insights and feedback. 4. Data analysis: Analysis of data from various sources, including climate models, socio-economic data, and adaptation measures.	1. Climate change poses significant risks to European societies, including increased extreme weather events, sea-level rise, and changes in temperature and precipitation patterns. 2. Existing adaptation measures are often fragmented and lack coordination, leading to gaps and inefficiencies. 3. There is a need for more effective climate change adaptation policies and strategies that take into account the specific needs and vulnerabilities of different regions and communities. 4. Increased investment in climate change adaptation is necessary to avoid significant economic and social losses.	n.a.

18	Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality	EEA	2024	Climate change adaptation and resilience in Europe, focusing on the impacts of climate change and the responses to these impacts at the national and EU levels	1. Assess the progress made by European countries in adapting to climate change. 2. Evaluate the effectiveness of climate change adaptation policies and measures. 3. Identify gaps and challenges in climate change adaptation and resilience. 4. Provide recommendations for improving climate change adaptation and resilience in Europe.	1. Literature review: A review of existing research and reports on climate change adaptation and resilience. 2. Surveys and questionnaires: Responses from EU Member States and other European countries on their climate change adaptation policies and measures. 3. Case studies: In-depth analysis of specific climate change adaptation projects and initiatives. 4. Data analysis: Analysis of climate-related data, such as temperature and precipitation trends, and impacts on human health, ecosystems, and the economy.	1. Climate change is already having significant impacts on Europe, and these impacts are expected to increase in the coming decades. 2. While progress has been made in climate change adaptation, many European countries still face significant challenges in responding to these impacts. 3. A lack of funding, coordination, and public awareness are major barriers to effective climate change adaptation. 4. There is a need for more integrated and inclusive approaches to climate change adaptation, involving multiple stakeholders and sectors. 5. The EU can play a key role in supporting climate change adaptation efforts in European countries, through policy guidance, funding, and knowledge sharing. 6. Overall, the report emphasizes the need for urgent and sustained action to address the impacts of climate change in Europe, and to build resilience and adaptability in the face of these impacts.	n.a.

19	European State of the Climate **ESOTC**	ECMWF (C3S) , WMO	2023	CLIMATE RISK	Climate in Europe (previous year's climate conditions, trends, and extremes)	Overview of climate trends of key events/ disaster related to climate change; focused also on Arctic; climate indicators + comparison with past trends and indicators		annual (in April or May)
20	JRC **PESETA IV**	JRC	2023	Understand the effects of climate change on Europe and how these effects could be avoided with mitigation and adaptation policies	Summary cards provide an overview of the main facts and figures of each of the key areas of work of the PESETA IV project	Focus on a number of climate change impact sectors. Assess how these effects could be avoided with "mitigation and adaptation policies.	Summary cards provide an overview of the main facts and figures of each of the key areas of work of the PESETA IV project	n.a.

21	Scaling nature-based solutions for **climate resilience and nature restoration**	EEA	2023	Nature-based solutions (NBS) for climate adaptation and disaster risk reduction	Presents a review of 97 NBS cases to demonstrate the effectiveness of NBS in addressing climate-related challenges	Literature review; Case study review; synthesis and analysis	Nature-based solutions (NBS) can contribute to climate resilience and biodiversity conservation: NBS can deliver multiple societal benefits and contribute to biodiversity conservation, but there is limited experience scaling solutions beyond local contexts. Scaling local initiatives is key: Accelerating and scaling NBS across Europe is crucial to achieving EU policy targets, and expanding and replicating local initiatives will be necessary to respond to the growing climate and biodiversity crises. To mainstream and fully implement the Nature-Based Solutions (NBS) concept, several steps are suggested: Regulatory measures and institutional arrangements to create favorable conditions and financial incentives. Targeted and coordinated governance. A scaling plan to realize the full potential of NBS. Establishing a taxonomy of NBS with baseline data (regional risk profiles, existing initiatives, etc.). Quantifying costs and benefits to channel public and private funding into large-scale implementation.	n.a.

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	MAIN CONCLUSIONS	Reporting Frequency
Economics for Disaster Prevention and Preparedness								
22	**Analytical indicators on physical risks**	ECB	2025	Risk indicators that consider risk related to climate change-induced natural hazards and assess how these affect firms ability to pay back loans and bonds and the performance of their equity). 9 areas covered: coastal flooding, river flooding, wildfires, landslides, subsidence, windstorms, water stress, droughts and rainfall variation	• To develop analytical indicators on physical risks related to climate change-induced natural hazards • To assess the potential impact of these risks on the financial system, particularly on euro area financial institutions • To provide a framework for benchmarking and comparing the economic impact of climate change across various hazards, climate scenarios, and countries	• The indicators are based on a combination of statistical methodologies and data from various sources, including the European System of Central Banks, the Intergovernmental Panel on Climate Change, and other international organizations • The indicators cover a range of natural hazards, including coastal flooding, river flooding, wildfires, landslides, subsidence, windstorms, water stress, droughts, and rainfall variation • The indicators take into account the location of debtors, the intensity of hazards, and the probability of hazard occurrence • The indicators are compiled using a framework that makes use of statistical methodologies typically applied to larger samples, and are not intended to be applied to single entities or neighbourhoods	• The indicators suggest that euro area financial institutions are exposed to a range of physical risks related to climate change-induced natural hazards • The potential exposure at risk (PEAR) indicator shows that adaptation strategies, such as flood protection, can significantly decrease flood risk • The normalised exposure at risk (NEAR) and collateral-adjusted exposure at risk (CEAR) indicators provide estimates of expected losses within a bank's portfolio, taking into account the intensity of hazards and the probability of hazard occurrence • The indicators highlight the importance of considering climate change risks in financial stability assessments and stress tests	n.a.
23	Climate Resilience Dialogue	17 ORGANISATION	2024	The report aims to stimulate investment in good climate adaptation by: Identifying climate-related risks and their impact on people, businesses, and assets; Analysing the factors contributing to the climate protection gap. Proposing solutions to reduce, share, and transfer climate-related risks. Highlighting good practices and lessons learned from past climate-related events. Presenting integrated approaches to increase climate resilience and meet the needs of various stakeholders	To narrow the climate protection gap, increase climate resilience, and find ways to address losses incurred from climate-related disasters. The dialogue aims to exchange views on how to address the climate protection gap and identify how the insurance industry can contribute to climate resilience	Involves bringing together existing insights, lessons, and learnings to propose actions and integrated approaches to address the climate protection gap. The dialogue allows for an open and comprehensive discussion among stakeholders, including public authorities, consumers, and the insurance industry, to formulate proposed actions, possible solutions, and good practices that increase climate resilience	The need for tailored approaches to resilience, enhanced multi-level and cross-sectoral cooperation, and the importance of risk awareness, preparedness, and proactive measures in the face of climate change. The dialogue also highlights the need for public-private partnerships, risk sharing and transfer approaches, and the development of innovative insurance-based solutions	n.a.

24	Towards a European system for natural catastrophe risk management	EIOPA, ECB	2024	Proposing a possible EU-level solution to address the widening gap in natural catastrophe insurance protection in Europe, by creating a two-pillar system: an EU public-private reinsurance scheme and an EU fund for public disaster financing	Propose a possible EU-level solution to address the widening gap in natural catastrophe insurance protection in Europe. The document aims to contribute to discussions on possible ways to reduce the insurance protection gap, while preserving the integrity of national insurance schemes and solutions	Analyses 12 existing national natural catastrophe insurance schemes worldwide and identifies their main objectives, design features, and challenges. The analysis draws from both a literature review and interviews with representatives of the schemes conducted in the first quarter of 2024. The document also builds on existing national and EU structures, such as the EU Solidarity Fund, and proposes a two-pillar system: an EU public-private reinsurance scheme and an EU fund for public disaster financing	• The existence of national insurance schemes correlates with higher insurance coverage, and these schemes can effectively support insurance coverage and minimize the insurance protection gap. A public-private reinsurance component at the EU level could help capture the broader economic benefits of insurance at EU level, alleviate the burden on national and EU public budgets, and promote a more coordinated and effective approach to managing natural catastrophe risks across Member States. • The proposed two-pillar system could enhance resilience to natural catastrophe risks at national and EU level, limiting related costs, and provide incentives for ex ante risk mitigation.	n.a.

25	Report on the monitoring of climate-related risk to financial stability	DG FISMA	2024	Monitoring of climate-related risk to financial stability in the European Union	To take stock of the analytical work being carried out in the EU on climate-related financial risks, identify key challenges related to measuring the impact of climate-related risks on financial stability, and outline the policy responses taken so far at EU level	Uses a combination of data analysis, scenario analysis, and stress testing to assess the impact of climate-related risks on financial stability. The methodology includes the use of climate scenarios developed by the Network for the Greening of the Financial System (NGFS), as well as stress tests conducted by the European Central Bank (ECB) and the European Systemic Risk Board (ESRB)	Climate-related risks have the potential to significantly impact financial stability in the EU, particularly in certain sectors and regions. The report also finds that the impact of climate-related risks on financial stability varies substantially between countries and economic sectors, and that there are potential systemic risks. The report highlights the importance of early action and an orderly transition to mitigate the risks associated with climate change	n.a.

26	Policy options to reduce the climate insurance protection gap	EIOPA, ECB	2023	The report discusses the growing concern of climate-related catastrophes in the EU and the need to address the widening insurance protection gap (which refers to the difference between the economic losses caused by climate-related disasters and the amount of losses that are insured.	It aims to solicit feedback on policy actions to tackle the climate insurance protection gap, including improving insurance policy design, developing public-private partnerships, and creating an EU-wide public scheme for natural disaster insurance. to identify policy options to reduce the climate insurance protection gap, incentivize risk mitigation and adaptation measures, and lower the share of economic losses from major natural disasters borne by the public sector	Ladder approach" to address the climate insurance protection gap, which involves a combination of private insurance, reinsurance, catastrophe bonds, and public sector intervention. The approach considers four layers: low to moderate loss layers, higher loss layers, national measures, and EU-level measures	A combination of private and public sector measures is needed to reduce the climate insurance protection gap. It also highlights the importance of risk-based incentives, impact underwriting, and catastrophe bonds in managing climate-related risks. Additionally, the document suggests that an EU-wide scheme could provide a backstop for national insurance schemes and help to reduce the protection gap. Overall, the document highlights the importance of addressing the climate insurance protection gap and provides a framework for policymakers and stakeholders to work together to reduce the gap and promote more effective risk management practices	n.a.

27	Climate change-related indicators	ECB	2023	The European Central Bank is developing climate indicators to: • Analyse climate risks; • Inform monetary policy; • Enhance transparency These indicators include sustainable finance, carbon emissions, and physical risks data	The main aim is to provide a set of indicators to monitor the ECB's sustainability performance and to support the development of sustainable financial systems in the European Union	The approach involves the use of a range of indicators, including environmental, social, and governance (ESG) metrics, to assess the sustainability performance of the ECB and the European financial system. The indicators are grouped into three categories: environmental sustainability, social sustainability, and governance sustainability.	ECB is committed to supporting sustainable development and that the use of sustainability indicators can help to identify areas for improvement and track progress over time. The indicators also provide a framework for the ECB to assess its own sustainability performance and to develop strategies for improvement.	n.a.

Reports category GLOBAL TRENDS REPORTS - HORIZON SCANNING

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	MAIN CONCLUSIONS	Reporting Frequency
GLOBAL TRENDS REPORTS - HORIZON SCANNING								
28	ESPAS GLOBAL TRENDS REPORT 2024-2040 Choosing Europe's future	EC (JRC), EP, EESC, EEAS	2024	Identifies 10 global trends that can increase until year 2040. Key uncertainties by 2040.	Does not produce policy options, highlight important aspects to reflect in policy making.	Horizon scanning, analysis of Megatrends.	Geopolitical chessboard: a world in flux • Trend: Shift from cooperation to competition and friction • Uncertainty: Future of China, Russia, and the US, and impact on global governance Mounting pressures on economic growth • Trend: Efficiency losses and costs of green transition and climate mitigation • Uncertainty: Extent of transactionalism in the global economy and potential reversibility Uneven demographic ramifications • Trend: Ageing population and decline in working-age population • Uncertainty: Migration, fertility rates, and population growth in developing countries Environmental emergency • Trend: Climate change and environmental degradation • Uncertainty: Risk of climate tipping points and biodiversity loss Energy transition Trend: Shift to renewable energy sources Uncertainty: Price and availability of critical minerals and grid capacity Equality: a complex and multidimensional picture Trend: Growing wealth gap and inequality Uncertainty: Impact of policy choices on combating inequality Technological acceleration and convergence Trend: Rapid deployment of new technologies Uncertainty: Balance between opportunities and threats, and governance of technology	Every 5 years
							Managing health • Trend: Growing burden of disease and healthcare costs • Uncertainty: Impact of technological innovation and global governance on health Changes in where and how we live • Trend: Urbanization and changing lifestyles • Uncertainty: Impact of technology and climate change on work and living conditions Democracy between threats and renewal Trend: Decline of democracy and rise of authoritarianism Uncertainty: Impact of technology and economic inequality on democracy	
29	ESPAS Horizon Scanning	EC (JRC), EU (ESPAS)	2024	Scanners collect each month around 100 signs of new. These are curated in workshops into weak-signals, indication possible new developments.	To find signs of new, that can be used in other projects as input.	Horizon scanning and sense-making	China's decline: Structural issues including demographic decline and real-estate collapse, combined with societal and resource related problems such as its 'lying flat' movement and energy shortages, could cause Chinese economic downturn. China's aging population and shrinking workforce, as well as its vacant properties and debt among developers, are posing significant strains on the Chinese economy. To counter this trend, China may invest more aggressively, protect and expand its hold over new technologies in addition to boosting its domestic consumption to reduce its reliance on exports. This risks to further exacerbate the unbalanced dependencies between China and Europe. China's economic troubles combined with its growing military capabilities could come to challenge regional and global stability. This would particularly be the case if China adopts a more aggressive posture in pursuing its interests, including on Taiwan, to deflect domestic attention away from internal issues through the pursuit of conflict with external enemies.	3 times per year

							CLIMATE DELAY DISCOURSES The recently released IPCC Working Group II report entitled 'Climate Change 2022: Impacts, Adaptation and Vulnerability', warns that "any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all." Climate delay discourses, distinct from those of denial or scepticism, focus mostly on negative social effects and doubts about possibility of mitigation. The most common logic of delay discourse is to redirect responsibility, push for non-transformative solutions, emphasise downsides of climate policies or surrender to climate change. METHANE EMISSIONS' UNDERESTIMATED IMPACT Methane is a primary energy source fuelling a quarter of the modern economy and a greenhouse gas with a high global warming potential. The IEA Global Methane Tracker 2022 shows that methane emissions from the energy sector are on the rise, but also that they are 70% higher than official figures. More generally, methane emissions are under-estimat ed, significantly accelerating since 2014 and could potentially further increase due to climate change. Climate scientists are calling for a change in how the potency of the gas is measured that would entail separating emissions targets for methane. This change would encourage governments towards more action beyond the voluntary Global Methane Pledge. TREE EXTINCTION CRISIS Reforestation programmes are seen as an important part of climate change mitigation, carbon capture and renewable energy targets. However, increasing numbers of signals point to negative consequences of many poorly managed and ill-conceived projects. One relates to "phantom forests" – failed high profile initiatives to plant millions of trees. Another is linked to proliferation of alien invasive tree species, which can have a negative effect on the ecosystems and incur considerable costs. At the same time climate-induced tree mortality is increasing, cause by pathogens, droughts/heat waves, fire/bark beetles,	

							and air pollution. The evidence produced by the Global Tree Assessment suggests that a third of the world's tree species are currently threatened with extinction. They call it a tree extinction crisis.	
30	Risks on the horizon	E C (JRC)	2024	Identifies, 40 risks and 10 risk clusters	Explores how not immediately risk related developments can develop into risks	Use of foresight methods, futures wheels and Delphi surveys. Futures wheels used to identify new risks and opportunities. Delphi survey	To address these challenges, the EU will need to develop a more circular economy, powered by decarbonized energy, green and digital technologies, and world-class talent [1]. The report concludes that the EU's future capacity and freedom to act will depend on its ability to make ambitious choices today, guided by its values and interests, and to work towards a more sustainable and resilient future [1].	Single publication

31	JRC Horizon Scanning March 2024 New OPECS for minerals and other resources	E C (JRC)	2024	Based on horizon scanning, the need for critical raw material creates new alliances and impacts the supply chains. Some countries focus to secure access while others having the material need water etc to produce them, this creates new form of alliances.	Explores the future implication of new form of alliances connected to critical raw material. Reflects on the implications for EU.	Using signs of new collected by EU institution wide network of scanners this weak signal was created during a sense making workshop.	The increasing demand for critical raw materials, such as metals and minerals, needed for a green transition is raising new geopolitical and trade issues. A few countries control a significant portion of these resources, leading to speculation about the formation of new global cartels to control the flow of raw materials. China is investing heavily in metals and mining overseas, with investments and contracts surpassing $10 billion in the first half of 2023. Other countries, such as Argentina, Bolivia, and Chile, are also seeking to manage the price of lithium and safeguard their resource interests. This increased competition and unstable supply chains could lead to the formation of international production cartels, which could disrupt markets and lead to trade disputes. However, it could also enable countries in Latin America and Africa to benefit more from their resources and support sustainable socio-economic development. The EU may need to consider alternative strategies, such as reducing dependencies on critical raw materials or supporting R&D in technology that is free of these materials.	Single publication

32	Council ART Research Prospects for 2024 geopolitical situation	Council of EU	2024	Qualitative analysis, the key trends, possible economic development, possible risks and opportunities should be watched.	Qualitative predictions based on some source: (geo-) politics, economy, environment, technology, and society	Qualitative analysis of information from Western sources and Chinese (Mainly geopolitical)	The year 2024 is expected to be marked by significant geopolitical challenges, economic instability, and environmental concerns. In terms of crisis management, several key trends and potential flashpoints have been identified: • Global Elections Supercycle: Over 40 national elections will take place in 2024, including in countries with significant global influence, such as the US, India, and Indonesia. These elections may lead to increased uncertainty and instability. • Ukraine Conflict: The conflict in Ukraine is expected to continue, with Russia likely to persist in its struggle with the West. The US and EU may re-evaluate their support, potentially leading to a decrease in aid. • Middle East Tensions: The Middle East remains at risk of escalation, particularly in the Gaza Strip, where Israel's military operation may lead to a wider conflict. The US and Iran may become more directly involved, increasing the risk of regional escalation. • Climate Change: Climate change is expected to continue to pose significant challenges, with 2024 potentially being one of the hottest years on record. Extreme weather events may disrupt global supply chains and lead to food shortages. • Cybersecurity Risks: The increasing use of AI and other technologies may create new cybersecurity risks, including the potential for large-scale targeted intrusions and the spread of disinformation. In terms of crisis management, it is essential for governments, organizations, and individuals to be prepared for these potential challenges. This includes: • Developing contingency plans: Governments and organizations should develop contingency plans to address potential crises, including those related to elections, conflicts, and environmental disasters.	n.a.

							• Improving cybersecurity: Governments and organizations should prioritize cybersecurity, including investing in AI-powered security solutions and implementing robust cybersecurity protocols. • Enhancing climate resilience: Governments and organizations should take steps to enhance their climate resilience, including investing in renewable energy and implementing climate-smart infrastructure projects. • Promoting international cooperation: Governments and organizations should prioritize international cooperation, including working together to address shared challenges such as climate change and cybersecurity risks. By being prepared for these potential challenges, governments, organizations, and individuals can reduce the risks associated with crisis management and promote a more stable and secure world.	

33	Reference foresight scenarios: Scenarios on the global standing of the EU in 2040	EC (JRC), EU (ESPAS)	2023	Four future looking scenarios	Four foresight constructed scenarios describing the global standing of the EU. They are part of the reference scenarios used in the Better Regulation Toolbox to stresstest polic options.	Identification of drivers of change and their possible future development are through a scenario development methodology making a scenario.	Four reference foresight scenarios for the European Union's (EU) global standing in 2040, developed through a participatory process involving over 100 experts. The scenarios explore the implications of different trends, uncertainties, and events on the EU's future. The main conclusion is that the EU's preparedness for an uncertain future requires a forward-looking framework that provides a reference for policymakers' debates about potential futures.	Single publication

	TITLE	Authors	YEAR	AREA/MAIN TOPIC	MAIN AIMS	METHODOLOGY/APPROACH	MAIN CONCLUSIONS	Reporting Frequency
GLOBAL TRENDS REPORTS - HORIZON SCANNING								
34	JRC Annual strategic foresight report: Towards a fair and sustainable Europe 2050: Social and economic choices in sustainability transitions	EC (JRC)	2023	This foresight study explores possible and necessary changes in the European social and economic systems as the European Union engages in managing sustainability transitions towards 2050. With this focus, the study presents strategic areas of intervention covering a new social contract, governance for sustainability, people and economy, and the global perspective on sustainability. The study reflects on the agency of EU actors (such as government at various levels, business, and communities) to address the strategic areas of intervention as part of collectively addressing sustainability transitions. The study builds on a participatory foresight exercise, which generated four foresight scenarios for a climate-neutral EU in 2050. Based on each scenario, a corresponding transition pathway was co-created and analysed through the process. The study presents and analyses these outputs of the process. The outputs can also serve as input to policymakers and practitioners interested in conducting new participatory exercises on sustainability transitions.	Strategic foresight to find pathways leading to social and economic choices in sustainability transitions. These have implication on EU:s open strategic autonomy	Development of foresight scenarios until year 2050 and finding transition pathways.	Exploration of possible futures for the European Union (EU) in 2050, where the EU has reached climate neutrality and become more environmentally sustainable. The study presents four foresight scenarios: Eco-states, Greening through crisis, Green business boom, and Global eco-world. Each scenario features a different primary driver of change in the environmental dimension of sustainability. The scenarios are not predictions but rather plausible trajectories that can help policymakers make informed decisions. The study also identifies key areas for intervention to achieve sustainability transitions, including the need for a new social contract, governance reforms, and a global perspective. It emphasizes the importance of a just transition, social cohesion, and participatory democracy in achieving sustainability goals. The EU's role in promoting democracy, security, and stability in a polarized world is also highlighted. The study suggests that the EU should invest in defence and security, including cybersecurity, and maintain its partnerships with like-minded states and city networks. The documents also provide information on the methodology used in the study, including a participatory process with experts and stakeholders. The study's findings can be used to inform policymaking and facilitate discussions about the future of sustainability in the EU. Overall, the study provides a comprehensive analysis of the challenges and opportunities facing the EU in its transition towards sustainability. It highlights the need for a coordinated and inclusive approach to achieving sustainability goals and provides recommendations for policymakers to consider.	Single publication

35	Future Shocks 2023, Anticipating and weathering the next storms	European Parliament (DGS: for External Policies of the Union, for Parliamentary Research Services and for the Presidency)	2023	Focus on specific risks and the capabilities and resilience of the EU s	Analysis of 15 key risks and the 10 policy response for the EU (highlights 15 risks related to geopolitics, climate change, health, economics and democracy that could occur in the coming decade, and 10 policy responses to address existing governance capacity and possible ways to enhance capabilities within the EU)	General description of identified risks (based also on the jrc data), challenges and gaps analysis of existing response, what to improve	Identification of several challenges: 1. Russian destabilization of Europe 2. China's assertive foreign policy and Taiwan unification ambitions 3. ollapse of the internet 4. Instrumentalisation of irregular migration at EU borders 5. Extreme weather events: Droughts and water scarcity 6. Biodiversity loss or collapse 7. Increase in antimicrobial-resistant infections 8. Security of energy supply in Europe 9. Elevated sovereign debt in Europe 10. Rising challenges to China's growth performance 11. Critical raw materials supply shock 12. Instability stemming from the financial technology sector 13. Strategic and systemic threats to the democratic information sphere 14. The economic crisis as an accelerator for social instability in democracies 15. Decline in mental health and societal well-being in young Europeans Analysis if each challenge, including ts potential impact on the EU and the world, and suggests possible scenarios and courses of action to mitigate or address the risk. Some of the key themes and takeaways from the report include: • The need for the EU to strengthen its resilience and preparedness in the face of various risks and challenges	ANNUAL

							• The importance of addressing the root causes of social and economic instability, such as poverty and inequality • The need for international cooperation and coordination to address global challenges, such as climate change and pandemics • The importance of protecting democratic values and institutions, and promoting fact-based information and media literacy • The need for the EU to invest in its human capital, including education and skills training, to address the challenges of the future • The importance of addressing the mental health and well-being of young Europeans, and promoting a healthy and sustainable lifestyle Overall, the report provides a comprehensive and nuanced analysis of the various risks and challenges facing the EU and the world, and suggests possible courses of action to mitigate or address these risks. The EU is facing a multitude of crises, including Russian aggression, Chinese assertiveness, economic instability, and climate change. Effective crisis management is crucial to mitigate the impact of these challenges. **Key Challenges:** • Managing the humanitarian and economic fallout of the Ukrainian war • Addressing the economic and social consequences of climate change • Mitigating the impact of biodiversity loss and ecosystem degradation • Managing the risks associated with antimicrobial resistance and pandemics	

							• Ensuring the security of energy supply and critical raw materials **Recommendations:** • Enhance early warning systems and risk assessment capabilities • Develop and implement effective crisis management plans and protocols • Foster international cooperation and coordination to address global challenges • Invest in research and development to address emerging risks and challenges • Promote sustainable and inclusive economic growth to reduce social and economic vulnerabilities • Strengthen the EU's resilience and preparedness through capacity building and training **Crisis Management Framework:** • Prevention: Identify and address root causes of crises • Preparedness: Develop and implement crisis management plans and protocols • Response: Respond quickly and effectively to emerging crises • Recovery: Support affected communities and promote sustainable recovery **Conclusion:** Effective crisis management is critical to mitigate the impact of emerging challenges and ensure the EU's resilience and prosperity. The EU must enhance its crisis management capabilities, foster international cooperation, and promote sustainable and inclusive economic growth to address the complex challenges it faces.	

36	JRC Annual strategic foresight report: Towards a green & digital future	EC (JRC), EU (ESPAS)	2022	Risks in transport, agriculture, energy production. Digital twin	How the green transition can be aided by digital sloutions. Deep-dive into two subjects in each area.	How digital innovations until year 2050 with different technological readiness levels can aid the green transition. Identification of necessary steps to reach it.	Emphasises the need for a twin transition, combining the green and digital transitions to achieve a climate-neutral, resource-efficient economy and society by 2050. The report highlights the importance of understanding the interactions between these two transitions, which are crucial for the EU's long-term objectives. The green transition requires the deployment of existing and new technologies, as well as significant investment in renewable energy, energy efficiency, and sustainable infrastructure. The digital transition can support this process by improving energy efficiency, reducing waste, and promoting sustainable consumption patterns. However, the report also notes that the twin transitions will require significant changes in various sectors, including energy, transport, industry, buildings, and agriculture. It emphasizes the need for a comprehensive and strategic approach to address the challenges and opportunities arising from these transitions. The report identifies key areas for action, including: • Strengthening the EU's resilience and open strategic autonomy in critical sectors • Galvanizing the twin transitions globally through rules-based multilateralism and values-based international cooperation • Strategically managing critical commodities and supplies • Strengthening social and economic cohesion along the transitions • Adapting education and training systems to the new socio-economic reality • Investing in technologies and infrastructures supporting twinning	Single publication

							• Implementing robust and reliable monitoring frameworks • Developing a future-proof and agile EU regulatory framework • Setting standards for competitive sustainability Ultimately, the report concludes that a successful twin transition will require a dynamic approach to anticipating change and adapting policy responses, while firmly maintaining the course towards long-term objectives.	
37	Shaping and securing the EU's Open Strategic Autonomy by 2040 and beyond	EC (JRC), EU (ESPAS)	2021	Looking at existing capacities, dependencies and vulnerabilities. What risks and opportunities future trends can bring.	Strategic foresight (To anticipate and prepare) on targets to receive EU open strategic autonomy. How to achieve it by	Development of scenarios describing the EU by year 2040 and beyond. Delphi survey to assess identified subjects	The European Union's 2021 Strategic Foresight Report outlines the challenges and opportunities that the EU will face in the coming decades. The report identifies four key global trends that will impact the EU's capacity and freedom to act: climate change and environmental challenges, digital hyper-connectivity and technological transformations, pressure on democratic models of governance and values, and shifts in the global order and demography.	Single publication

38	JRC Annual strategic foresight report: Charting the course towards a more resilient Europe	EC (JRC)	2020	Discusses the first structural lessons learnt from the COVID-19 crisis, and explains how foresight can help strengthen Europe's long-term resilience in an era of fundamental and rapid change. It analyses the EU s resilience across four dimensions: social and economic, geopolitical, green and digital.	Creation of resilience dashboards, Commission Foresight Agenda	Strategic foresight can inform resilience-enhancing policies across four dimensions. It can help anticipate developments likely to have adverse impacts, to strengthen corresponding resilience through structural changes as well as taking into account the impact of current and future crises on relevant megatrends and emerging issues. Policies benefiting from strategic foresight can better mitigate the vulnerabilities and strengthen the capacities	Outlines how the European Union can strengthen its resilience in the face of global challenges. The report identifies four dimensions of resilience: social and economic, geopolitical, green, and digital. The social and economic dimension of resilience refers to the ability to tackle economic shocks and achieve long-term structural change in a fair and inclusive way. The report highlights the importance of a highly skilled workforce, competitive economy, and social systems that protect people from adverse events. However, it also notes that the COVID-19 crisis has exposed health and social vulnerabilities in Europe, including inadequate healthcare systems and social protection measures. The geopolitical dimension of resilience relates to Europe's ability to bolster its "open strategic autonomy" and global leadership role. The report notes that the EU is considered a trusted partner and responsible leader, but faces challenges such as the shift of power to the East and South, and the need to protect its economic sovereignty. The green dimension of resilience refers to the EU's abil ity to reach climate neutrality by 2050 and mitigate the impact of climate change. The report highlights the importance of a clean and circular economy, and notes that the EU is a global leader in this area. However, it also notes that climate change is making extreme weather events more frequent and intense, and that the EU's current production and consumption model is unsustainable.	Single publication

						revealed by the crisis, opening new opportunities and making Europe more resilient	The digital dimension of resilience refers to the EU's ability to ensure that digital technologies preserve and enhance human dignity, freedom, equality, security, democracy, and other European fundamental rights and values. The report notes that digital technologies have been instrumental in keeping economies and societies running during the pandemic, but also highlights the risks of cybersecurity threats and the digital divide. Overall, the report emphasizes the importance of strategic foresight in identifying potential challenges and opportunities, and in developing policies that strengthen the EU's resilience across all four dimensions.	

Annex 2

Comparative overview table with all the risks

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Questionnaire guidelines and definitions

Cross-border risk	The identification of key risks with a potential cross-border impact and the estimation of their respective impacts might consider: i. impacts resulting from risks generated in a neighbouring country or countries ii. impacts that spill over into a neighbouring country or countries iii. impacts affecting two or more countries simultaneously (European[UG(1] Commission, 2019).
Emerging risk	Emerging risks are risks that may be • new risks; • difficult to assess (with traditional risk assessment and management approaches) likelihood of harm; • difficult to foresee, i.e. it is difficult to assess the probability that a certain consequence will occur at a specific time / place / condition; • risks resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard; • new or familiar risks that become apparent in new or under unfamiliar conditions. Definitions of emerging risks also include the concept of newly created risks; newly identified/ noticed risks; increasing risk, or risk becoming widely known or established (European Commission, 2019).
Climate-related	Risks related to climate change, including risks that are projected to increase in frequency, severity, or impact due to climate change. Risks for which climate scenarios are relevant in risk assessment.
High Impact, Low Probability Risks	There is no universally agreed definition of what a high-impact, low probability risk is, an operational definition of such risks was adopted for the purpose of establishing he rescEU reserve capacities, since their aim is to help respond to extreme situations characterised by (European Commission, 2019): a. the unpredictability or extraordinary nature of a disaster; b. the scale of the disaster, including mass casualties, mass fatalities, and mass displacement; c. the protracted duration of a disaster; d. the degree of complexity of a disaster; e. the potential risk of severely disrupting the functioning of the national Government, including the provision of social, environmental, economic and public health services or the disruption of critical entities; f. geographical range, including the potential for impacts to spread across borders; g. other factors such as full activation of the Council's Integrated Political Crisis Response (IPCR) arrangements or citing the solidarity clause under Article 222[30] of the Treaty on the Functioning of the European Union that have a low probability of occurrence but a high potential impact, including risks that are characterised by their unpredictability, extraordinary nature, scale, protracted duration, complexity, and potential to disrupt critical entities. High impact, low probability risks are taking into consideration the long-term perspective of risk management. Risks that for the near future are considered very unlikely and may discourage from risk management efforts, but when raising the time horizon become significant due to the high impact, e.g. Covid pandemic. (Poljanšek et al., 2021).
Loss and damage (past events)	Data and statistics are important in understanding the impacts and costs of disasters. Systematic data collection and analysis can be used to inform policy decisions to help reduce disaster risks and build resilience. Disaster loss databases allow disaster risk managers to explore patterns and trends in disaster risk on the basis of past events. Understanding these patterns and trends can help in anticipating future losses from extensive events (frequent events) and in understanding whether disaster risk management is effective in reducing this kind of risk. (European Commission, 2019). **Direct losses** refer to the physical or structural impact caused by the disaster such as the disruption of infrastructure caused by natural hazards or man-made threats[31]. **Indirect effects** refer to the physical or structural impact caused by the disaster such as the disruption of infrastructure caused by natural hazards or man-made threats.
Loss and damage data	List if there are loss and damage databases that collect the relevant loss data by sectors.
Potential impacts (future)	The process of risk assessment involves risk identification, risk analysis and risk evaluation. The outcomes of the risk assessment inform decision-makers on how to treat the risk by feeding into DRM planning and the implementation of prevention and preparedness measures. Getting an initial idea of how the potential impacts are expected to evolve over a period of time can also help with risk comparability. (Poljanšek et al., 2019) **Direct potential impacts** refer to the physical or structural impact caused by the disaster such as the destruction of infrastructure caused by the force of high winds, flooding or ground shaking. **Indirect effects** are the potential subsequent or secondary results of the initial destruction, such as business interruption losses..

30 EU integrated political crisis response arrangements (IPCR) lays down arrangements for the European Union (EU) (*http://eur-lex.europa.eu/EN/legal-content/glossary/european-union.html)* integrated political crisis response (IPCR). These strengthen the EU's ability to take rapid political decisions when facing major internal or external crises* with a wide-ranging impact or political significance, whether they originate inside or outside the EU. Crises for which IPCR has been activated have as a rule been cross-sectoral in nature. *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:4651491*

31 UNDRR, Understanding disaster risk, Key concepts: Direct and indirect losses: *https://www.preventionweb.net/understanding-disaster-risk/key-concepts/direct-indirect-losses*

Level uncertainties	Uncertainty in risk assessment refers to the lack of complete knowledge about current and future risks, which can stem from the inherent variability of the physical environment or from limited knowledge, measurement, or modelling capabilities. Uncertainty is present at every stage of the risk assessment process, from conceptualisation to data collection (including data imprecision) imprecision and analysis, and should be explicitly identified, documented, and communicated. It can be expressed qualitatively (expert opinion) or quantitatively (such as probability density functions), and its transparent treatment is essential for sound decision-making. It can also reflect ambiguously defined concepts or terminology, incomplete understanding of critical processes, and uncertain projections of human behaviour. (Casajus Valles et al., 2021; IPCC, 2022).
Risk Drivers	Risk driver identification and analysis are important elements in assessing the probability of a certain hazards in the future and identifying new potential risks. Over the three reporting cycles for Article 6 summary reports, climate change, urbanisation and globalisation-related issues have been considered consistently as risk drivers. Other risk drivers include technological developments, and changing security/political landscape, global financial and economic developments, socio-economic and demographic developments and environmental degradation. (European Commission, 2024)
Cascading hazards and/or impacts	**Cascading hazard** processes refer to an initial hazard followed by a chain of interrelated hazards (e.g., earthquake triggering landslide, landslide triggering flooding, flooding triggering further landslides). (Gill et al., 2022) **Cascading impacts** are those in which the impact of a physical event or the development of an initial technological or human failure generates a sequence of events in human subsystems that results in physical, social or economic disruption. Thus, an initial impact can trigger other phenomena that lead to consequences with significant magnitudes. (Gill et al., 2022)
Compound relationships	Two or more hazards may impact the same region and/or time period with impacts different (greater, lesser) than their sum. These compound relationships can take different forms, including (i) a primary hazard triggering multiple secondary hazards simultaneously, and (ii) two independent hazards impacting the same region and/or time period (or in close succession). (Gill et al., 2022)
Gaps and needs (urgent)	Are there any clear gaps and/or needs which affects the risk management (e.g. data accuracy or missing data, lack of protocols/standards, gaps in methodology, gaps in scientific literature /research gaps). Gaps and needs are sub-divided, when possible, into operational, policy and research.
Policy reference/s	List the relevant policy references in place and/or in the pipeline for the management of the risk.
Adaptation measures in place & Recommended adaptation measures	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. (IPCC, 2014)

Mitigation measures in place & Mitigation measures going forward	The lessening of the potential adverse impacts of a hazardous event (including those that are human-induced) through actions that reduce hazard, exposure and vulnerability. For example for Climate Change, the actions for mitigation are related to human intervention to reduce emissions or enhance the sinks of greenhouse gases. (IPCC, 2022) (UNDRR, 2017)

Cyber threats

Cyber threats cover four main risks, which are artificial intelligence risks, cyber incidents in healthcare, cybersecurity and disinformation[32]. Brief introduction is provided below for some of the risks covered in this category.

Artificial intelligence

In the context of this report, and the process followed to capture risk information from experts in the respective fields, the discussion focused on possible negative impacts of new technologies such as artificial intelligence in specific contexts within civil protection scenarios. As such, it is not a thorough and comprehensive assessment of all the risks or possible impacts associated with AI or any technological development. In a broader context, the AI Act (European Parliament and Council, 2024b) provides a key regulatory reference. In the case of general-purpose AI models, systemic risks are mentioned which include, but are not limited to, any actual or reasonably foreseeable negative effects in relation to major accidents, disruptions of critical sectors and serious consequences to public health and safety; any actual or reasonably foreseeable negative effects on democratic processes, public and economic security; the dissemination of illegal, false, or discriminatory content.

Cyber incidents in healthcare

Cyber attacks on healthcare settings have recently increased in frequency and magnitude. They have caused significant damage to infrastructures, compromising both continuity and quality of services. Accordingly, policy makers (e.g. von der Leyen, 2024) recognise cyber attacks as a public health problem of growing urgency, due to the accelerating digitisation of healthcare and the roll-out of AI-enabled and connected devices. Apart from causing economic damage, cyber attacks cause harm to patients, e.g. delays in diagnosis, treatment or interruption of emergency services. These may cause adverse health outcomes (illness, impairment or even death). The severity of this problem is presently not fully clear, which in part is due to a lack of comprehensive and consistent frameworks for characterising cyber incidents and enabling collaboration across the entire value chain. Reliable data are thus sparse or contradictory. Better characterisation and understanding of cyber incidents in healthcare settings would be required as a fundamental prerequisite to improve the reduction of vulnerabilities and hence risks on public services and assets as well as, most importantly, the health of patients.

Cybersecurity

Cyberattacks on businesses, organisations and infrastructures are on the rise in Europe. The European Agency for cybersecurity (ENISA) observed a significant increase in the reported cyberattacks in the EU during the first half of 2024 compared to the second half of 2023, with a total number of more than 11000 incidents in the period between July 2023 and June 2024 (ENISA, 2024). Of these, more than 300 incidents were referred to have targeted two or more EU Member States. The trend is increasing not only in volume but also in terms of economic impacts: the annual cost of cybercrime to the global

32 Disinformation is grouped together with cyber and hybrid threats, however disinformation can also be part of traditional media campaigns, FIMI, and can be carried out as disinformation as a business.

economy is estimated to have reached €5,5 trillion at the end of 2020, double the figure of 2015[33]. Other than economic damages, cyberattacks have also the potential to interfere, even drastically, with the functioning of critical infrastructures, communications networks and transport systems, among others, leading to the disruption of energy supply, communication capabilities and transportations. In extreme cases, also physical risks for people can derive from a cyberattack (e.g. train accident due to control systems out of order or explosions in energy generation plants). The motivation behind a targeted attack can be diverse, but in general it falls into one of more of these categories: financial gain (cybercrime), espionage, destruction (state-sponsored groups) and ideological (hacktivists). Especially after the geopolitical evolution of the last years, geopolitical-linked reasons continue to be a strong driver for cyber malicious operations, which are also a fundamental part of Hybrid operations, including to produce highly disruptive multi-domain attacks.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Artificial intelligence	Yes	Yes	Yes	Yes
Cyber incidents in healthcare	Yes	Yes	No	Yes
Cybersecurity	Yes	Yes	No	No
Disinformation	Yes	No	Yes	Yes

AI itself is not inherently a risk, but its misuse, unintended effects, or loss of control could lead to cross-border risks, especially with advanced models whose rapid capability growth makes continuous risk assessment necessary. Additionally, the energy efficiency of AI and its environmental sustainability should be monitored, although it also offers societal benefits like aiding climate change mitigation and adaptation.

Cyber incidents in healthcare can range from targeting individual hospitals to affecting entire regions or countries, with potential spill over effects across the EU. While the likelihood of all EU health systems being simultaneously compromised is very low, the consequences would be devastating.

Cybersecurity incidents occur frequently, and while individual episodes may have limited impact, their cumulative effect is significant. .

While **disinformation** is not a direct threat such as cyber incidents in healthcare, the indirect effects have high impact: disinformation to meddle with democratic elections, to deny or downplay climate change, to strengthen vaccination hesitancy. This is why, European Commission President Ursula von der Leyen emphasized that "the European Democracy Shield is a crucial step towards protecting our democracy and ensuring that our citizens can make informed decisions" (European Parliament and Council, 2024c).

Loss, damages, and potential impacts

Artificial intelligence	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	N/A	N/A	N/A	N/A
Potential impact (next 10 years)	Low	Low	High	High

33 Cyber threats in the EU: *https://www.consilium.europa.eu/en/infographics/cyber-threats-eu/*

Loss and damages are indicated as not applicable due to the limited historical data with limited confirmed incidents or events with AI as a predominant factor causing a high economic and/or non-economic impact.
Potential direct **impacts** caused by AI itself are marked as low. Rather, unintended effects of the use of AI or its malicious use can lead to subsequent impacts. AI can play a role in the materialisation of systemic risks in relation to major accidents or disruptions of critical sectors and infrastructure, or in relation to major cyber incidents, with potentially high economic impact. Similarly, AI can play a role in risks impacting individuals and societies, e.g. through intentional misuse or unintended issues resulting in public health and safety crises, negatively affecting democratic processes, or potentially lowering entry barriers that lead to increased biological or nuclear risks or the creation of weapons.

Data collection: While there are some emerging AI risk databases, these do not systematically cover loss or damage aspects, rather providing a qualitative account of incidents involving AI.

Level uncertainties: Given the rapidly evolving nature of AI technology and its relatively recent adoption at scale, there is a **high level of uncertainty** about some of the potential risks emerging through the increased use of AI, or a rapid advancement in the capabilities of the most powerful AI models.

Cyber incidents in healthcare	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

The direct and indirect **losses** and **potential impacts** are deemed high for the affected entity and for the stakeholder interacting with the affected stakeholder, with no distinction between economic and non-economic impacts. The potential impacts of simultaneous attacks on health systems in the EU could be devastating.

Data collection: ENISA is regularly providing reports. JRC has published a report (Reina et al. 2024), specifically looking at adversity in patients resulting from cyber incidents. Ample scientific literature; however contradictory.

Level uncertainties: High uncertainty currently to which extent cyber incidents have led to health impacts and health adversity in patients. In the literature there is conflicting information (e.g. surveys of physicians results in responses such as "increased mortality"), while, typically, official reporting following cyber incidents outlines service outages, delays etc., without further specifying to which extent this affected patients.

Cybersecurity	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	Low	N/A	N/A
Potential impact (next 10 years)	High	Low	High	Low

The annual cost of cybercrime to the global economy was estimated at €5.5 trillion by the end of 2020, doubling since 2015 (ECB, EIOPA, 2024). While there are no statistics on non-economic damages, there have been no confirmed reports of direct harm to populations, such as deaths, resulting from cyberattacks. However, such outcomes remain possible if critical infrastructures like nuclear plants or dams are targeted.
In general, cyberattacks are forecasted to increase, leaving therefore the potential impact at least at the same level as the current one (ENISA, 2023).

Data collection:

- ECB publication: Towards a framework for assessing systemic cyber risk (ECB, 2022).
- Statista[34]
- European Commission publication: A cybersecure digital transformation in a complex threat environment (European Commission, 2023)

Level uncertainties: Low at operational level, **medium/high** at strategic level. At an operational level (e.g. single cyber incident, single organisation) methodologies and processes to tackle the cyber risk are well defined. Nevertheless, in the long-term view, it is still unclear how the technological evolution will affect the cyber risk, and therefore it is difficult to forecast its evolution and anticipate it with the appropriate measures.

Disinformation	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium		Medium	
Potential impact (next 10 years)	Medium		Medium	

Disinformation has led to both economic (e.g. destruction of telecommunications infrastructure during the pandemic due to narratives about 5G technology) and non-economic impacts (e.g. loss of life during the COVID-19 pandemic due to ingestion of bleach or other detergents).

Data collection: EUvsDiSiNFO[35], an EU initiative aimed at countering disinformation and propaganda..

Level uncertainties: Medium

Risk drivers and interactions

Artificial intelligence

Risk drivers	• Technological developments; • Changing security landscape (e.g. potential use of AI for weapons development or cyber offence); • Socio-economic factors (e.g. potential risk of use of AI for persuasion and manipulation, disinformation campaigns and inauthentic behaviour, or large-scale discrimination); Global financial and economic developments (e.g. accelerating automation and reliance on AI, potentially leading to increased risks).
Hazards triggering	• Armed conflicts
Hazards triggered by	• Disinformation; • Cybersecurity; • Hybrid threats; • Disruption of essential services; • Terrorism.
Cascading impacts	• Industrial accidents; • Disruptions of critical sectors; • Serious consequences to public health and safety; • Negative effects on democratic processes; • Public and economic security; • Dissemination of illegal, false, or discriminatory content.
Compound relationships	• Terrorism; • Climate events and natural disasters; • Epidemics; • Migration

Cyber incidents in healthcare

Risk drivers	• Digitalisation (increasing digitisation of health, increasing uptake of AI enabled devices, Internet of things (IoT), heterogeneity of use environments in health care settings)
Hazards triggering	• Cybersecurity hazards (ransomware, malware, denial of service, social engineering, phishing, supply chain attack); • Vulnerabilities (Unpatched systems, Lack of encryption, Unsecured medical devices, Weak password policies, Lack of training and awareness, Weak security controls and measures)
Hazards triggered by	• Disruption of essential services; • Cybersecurity
Cascading impacts	• Health impacts (delayed treatments/surgeries, patient harm, e.g. death, permanent health deterioration, impairment etc.) (Reina et al., 2024; NHS Cyberattack in UK Inflicted Long-Term Harm on Patient Health[36])
Compound relationships	• Human health risks (CCDCOE, 2020); • Disruption of essential services

Cybersecurity

Risk drivers	• Technological developments; • Changing security landscape; • Weak governance (lack of awareness/education, supply chain vulnerabilities, lack of investments)
Hazards triggering	• Organised crime landscape • Hacktivist threat landscape • Armed conflicts • Hybrid threats • Espionage • Disinformation
Hazards triggered by	• Financial risk • Disinformation • Disruption of essential services • Health risk

34 Average cost of all cyber attacks and largest single cyber attack to European firms in 2023, by country, 2024, available at *https://www.statista.com/statistics/1008178/european-firms-cyberattack-target-cost/*

35 EUvsDISINFO website: *https://euvsdisinfo.eu/*

36 NHS Cyberattack in UK Inflicted Long-Term Harm on Patient Health. *https://www.insurancejournal.com/news/international/2025/01/15/808371.htm*

Cascading impacts	• Power outage; • Disruption of essential services (communication, transport services)
Compound relationships	• Cybersecurity and Armed conflicts[37]; • Disruption of essential services and Supply chain risk[38]

Disinformation

Risk drivers	• Geopolitical developments; • Changing security landscape; • Weak governance; • FIMI.
Hazards triggering	• All hazards
Hazards triggered by	N/A
Cascading impacts	• Undermining trust in institutions, science, • government experts • Erosion of trust in democratic institutions
Compound relationships	• Disinformation and health risks;[39] • Disinformation and climate change (exacerbating wildfires, droughts, storms);[40] • Disinformation and AI; • Disinformation and Armed conflicts[41]

37 In the first hours of the Russian invasion of Ukraine, a cyberattack against the satellite internet systems of the American communication company Viasat affected the KA-SAT network. Among the various impacts, in Germany the monitoring and remote control system of various wind turbines went offline for one hour. Since the attack has been condemned by EU, US and UK institutions as a Russian operation, we could argue that the "International Armed Conflict" hazard, together with the cybersecurity hazard caused "Radio and Other Telecommunication Failures".
https://en.wikipedia.org/wiki/Viasat_hack;
https://www.pv-magazine.com/2022/03/01/satellite-cyber-attack-paralyzes-11gw-of-german-wind-turbines/

38 The NotPetya malware (in 2017), among other things, temporarily knocked out the radiation monitoring system of Chernobyl and disrupted the production and distribution of vaccines produced by Merck. In this example, we therefore have two hazards (i.e. "Critical Infrastructure Failure" and "Supply Chain Failure" that were triggered by the same cyberattack.
https://www.zoho.com/workplace/articles/notpetya-cyberattack.html;
https://westoahu.hawaii.edu/cyber/regional/gce-us-news/notpetya-ransomware-disrupts-merck-vaccine-production

39 Fake news linking COVID-19 vaccines to microchips or infertility led to vaccine hesitancy, reducing herd immunity.
Compounding impact: Lower vaccination rates allowed the virus to mutate (e.g., Delta, Omicron variants), prolonging the pandemic and increasing strain on healthcare systems.
Example: The myth that 5G caused COVID-19 led to attacks on telecom towers in the UK, disrupting communication infrastructure during a health crisis.

40 Fossil fuel industry-backed narratives falsely claiming climate change is a hoax slowed global policy action.
Compounding impact: Delayed action leads to worsening climate disasters, affecting economies, agriculture, and human migration
Example: The spread of fake studies downplaying climate change in media and politics delayed necessary regulations, exacerbating wildfires, droughts, and hurricanes.

41 Military conflicts involve geopolitical alliances, economic sanctions, and public perception. Disinformation effect: Propaganda spreads false narratives about war crimes, enemy actions, and battlefield outcomes.
Compounding impact: Misinformation can prolong conflicts by shaping international responses or justifying military actions.
Example: In the Russian war against Ukraine, false reports about bioweapon labs in Ukraine fueled conspiracy theories that justified Russia's invasion

Gaps and needs

	Operational	Research	Policy
Artificial intelligence	Continued adoption and implementation of established trustworthy AI practices across industries.	On-going development of AI with increased capabilities to be complemented with new effective approaches for risk mitigation.	Ongoing development of technical standards, guidelines and codes of practice supporting the implementation of existing AI regulation.
Cyber incidents in healthcare	Human resources - interdisciplinary at health settings, to prevent, mitigate, resolve the problems resulting from attacks. Inadequate incident response planning and coordination Limited cybersecurity resources and expertise..	Better incident charac-terisation of incidents in health settings: prereq-uisite for targeted miti-gation Independent audits to investigate longer term effects, notably adverse effects on patients.	Common EU reporting requirements (simple and effective, not too much burden) to enhance understanding and support effective countermeasures
Cybersecurity	Correct implementation of methodologies and good practices	No evident gaps	Political willingness to do the right investments
Disinformation	Lack of access to data from social media platforms[42]	Analysis of trends e.g. for climate change, mi-gration, public health, man-made and natural disasters, geopolitical events such as the Rus-sian war of aggression against Ukraine	Lack of legal mandate to profile accounts that are known to often spread mis- and disin-formation

Policy reference and adaptation/mitigation measures

Artificial intelligence

Adaptation measures in place	N/A (Considering the emerging nature of some of the risks discussed, we cannot provide an established list of adaptation measures for AI-related risks)
Recommended adaptation measures	N/A

42 There is an ongoing discussion for exploring how Art. 40 (12) DSA (European Parliament and Council, 2022b) could enable us to request data from social media platforms

Mitigation measures in place	• Measures related to AI risk management,; • data quality and governance, transparency; • record keeping; • human oversight of AI; • accuracy; • robustness and cybersecurity; • technical measures for AI alignment; • adversarial testing;[43] **NOTE:** Examples of measures and requirements captured in regulatory frameworks such as the EU AI Act. Established measures have been adopted by AI practitioners on a voluntary manner. Going forward, with the application of AI regulatory frameworks, some AI systems and models posing higher risk will be legally mandated to implement the necessary mitigation measures. Recommended mitigation measures
Recommended mitigation measures	As new generally accepted, established AI risk mitigations appear and evolve.
Policy references	Artificial Intelligence Act - (European Parliament and Council, 2024b)

Cyber incidents in healthcare

Adaptation measures in place	None that are organised at EU level to our knowledge Health is MS domain, often even regional.
Recommended adaptation measures	Establishment of a "Centre for excellence on cybersecurity in health settings" (EU level, working with relevant COM services, ENISA and MS and regions) for providing a. training ; b. advising on countermeasures / vulnerabilities, operational issues e.g. skill requirements for local teams; c. raising awareness (dialogue with medical associations, health system managers, policy makers); d. engaging with industry to promote cybersecurity "by design" (Internet of Things (IoT), medical devices, AI in health etc.)..
Mitigation measures in place	Varying at local level. These, however, may not always take specifics of the health sector sufficiently into account. Specific examples: • Technical measures (e.g. implement multi-factor authentication, implement network segmentation, use intrusion detection and prevention systems, establish update and patch systems plans, use secure communication protocols) • Administrative measures (e.g. develop a cybersecurity policy, conduct regular risk assessments, provide regular cybersecurity training, implement incident response planning, establish a security awareness program) • Organizational measures (develop a cybersecurity culture, establish a cybersecurity governance structure, conduct regular cybersecurity audits, establish a cybersecurity budget)

43 Alignment creating AI which is aligned with human intent and goals, as well as principles

Recommended mitigation measures	Evidence-based catalogue of most common vulnerabilities in health settings including measures to avoid these. (JRC (F.2) is working on a conceptual framework ("toolbox") for generating reliable evidence on cyber incidents in health settings)
Policy references	Von der Leyen Political Guidelines: within 100 days the Commission will present a plan how to strengthen cyber resilience of healthcare settings (Von der Leyen, 2024); Health-specific: MDR/IVDR (European Parliament and Council, 2017) + Cybersecurity guidance General: NIS2 (European Parliament and Council, 2022), Cyber resilience Act (European Parliament and Council, 2024a)

Cybersecurity

NOTE: In the cybersecurity risk case, we believe that adaptation and mitigation measures are the same as they are taken both to mitigate the impact of cyber-attacks, and as an adaptation measure to the existence of the risk itself, that can never be totally eliminated

Adaptation measures in place	Technological developments; Investments on infrastructures; Regulations to enforce the implementation of correct methodologies/processes; Awareness raising measures;
Recommended adaptation measures	As above (see NOTE)
Mitigation measures in place	As above (see NOTE)
Recommended mitigation measures	As above (see NOTE)
Policy references	Cyber Resilience Act (European Parliament and Council, 2024a) Cyber Solidarity Act (European Parliament and Council, 2025) Cybersecurity Act (European Parliament and Council, 2019) NIS 2 Directive (European Parliament and Council, 2022a)

Disinformation

Adaptation measures in place	EUvsDISINFO, European Digital Media Observatory (EDMO)[44]
Recommended adaptation measures	In-house efforts at the European Commission to improve analysis of disinformation trends

44 European Digital Media Observatory (EDMO): https://digital-strategy.ec.europa.eu/en/policies/european-digital-media-observatory

Mitigation measures in place	• EUvsDISINFO; • EDMO • Digital Services Act (DSA) (European Parliament and Council, 2022b) regulating on line platforms (social media, online market places etc.) • EU AI act for regulating AI (European Parliament and Council, 2024b)
Recommended mitigation measures	Make analysis of disinformation part of briefing material, work on communication efforts, raising situational awareness
Policy references	Digital Services Act (European Parliament and Council, 2022b) Code of Practice on Disinformation and Code of Conduct on Disinformation[45]

Meteorological & Climatological

Meteorological & Climatological risks covers six risks: **heatwave, cold wave, convective storm, tropical cyclone, drought** and **wildfires**.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Heatwave	Yes	No	Yes	No
Cold wave	Yes	No	Yes	No
Convective storm	Yes	No	Yes	No
Tropical cyclone	Yes	No	Yes	No
Drought	Yes	Yes	Yes	Yes
Wildfires	Yes	Yes	Yes	No

Heatwaves are identified as a cross-border risk due to their ability to impact vast regions, causing cascading effects across economic sectors, borders, and systems. Although not classified as an emerging risk, the increasing frequency and intensity driven by climate change introduces new conditions that align with emerging risk characteristics. As a climate-related risk, heatwaves are strongly linked to global warming, with studies showing significant increases in their frequency and severity, particularly in southern European countries under higher temperature scenarios (Feyen et al., 2020; IPCC, 2023). However, heatwaves are not inherently high-impact low-probability risks, except in extreme cases with long return periods (e.g., 1000 years), although their recurrence is becoming more frequent due to climate change.

Cold waves are considered a cross-border risk due to their ability to affect large areas and cause cascading impacts across economic sectors, systems, and regions. They are not classified as an emerging risk, as their characteristics are well understood. As a climate-related risk, cold waves are projected to decline in frequency and intensity with global warming, significantly reducing exposure and fatalities across Europe, particularly in southern and northern regions (Feyen et al., 2020). While extreme cold events are expected to become increasingly rare, they are not categorized as high-impact low-probability risks under current conditions.

Convective storms are powerful weather phenomena that arise from the upward movement of warm, moist air. They can manifest in various forms, each with unique characteristics and impacts.

45 Signatories of the Code of Practice on Disinformation, "Strengthened Code of Practice on Disinformation," 2022, available at https://digital-strategy.ec.europa.eu/en/policies/code-practice-disinformation

Tornadoes are violently rotating air columns that can cause significant damage due to their high wind speeds. Wind storms, such as straight-line winds and derechos, are long-lived wind storms associated with rapidly moving showers or thunderstorms. Rain storms, such as flash flooding, can lead to intense, short-duration rainfall that overwhelms drainage systems. Winter storms and blizzards involve heavy snowfall and strong winds, causing reduced visibility and dangerous travel conditions. Derechos are widespread, long-lived wind storms associated with a mesoscale convective system. Lightning, a common feature of thunderstorms, can cause fires and pose a significant risk to life and property. Thunderstorms, characterized by thunder and lightning, can produce heavy rain, hail, strong winds, and tornadoes. Hailstones, formed in strong updrafts within thunderstorms, can cause significant damage to crops, vehicles, and buildings. Sand/dust storms occur in arid regions where strong winds lift loose sand and dust from the ground, reducing visibility and causing respiratory issues. Understanding these storms' characteristics is crucial for preparing and mitigating their effects (WMO, 2021; Geiger et al., 2017a). They are identified as a cross-border risk due to their ability to cause widespread impacts across regions and sectors.

Convective storms are not typically classified as emerging risks in themselves. However, the convective storms can be considered an emerging risk (based on the definition of emerging risks) due to their complexities and uncertainties in assessment, forecasting, and management. They are difficult to assess due to changing geography, frequency, and intensity, making it difficult to predict their likelihood of harm. They are also difficult to foresee due to their wide impact and it is hard to assess the probability that a certain consequence will occur at a specific time, place, or condition (Geiger et al., 2017b; Geiger et al., 2017c; Pérez-Alarcón et al., 2023).

Climate scenarios play a crucial role in the risk assessment of convective storms. Climate change can influence the frequency, intensity, and geography of these storms. The various climate-related factors that are relevant to the impact of convective storms are rising temperatures, changing precipitation patterns, and increased atmospheric moisture. However, convective storms are not categorized as high-impact low-probability risks under current conditions.

Tropical cyclones are classified as a cross-border risk due to their ability to impact multiple countries, spreading destruction across borders[46]. They are not considered an emerging risk, but climate change has capacity to shift patterns and locations, change frequency and intensity, all of which would be new conditions with respect to known risk. As one of the most devastating hazards - tropical cyclones (also known as typhoons and hurricanes) are observed, monitored, and forecasted by six tropical cyclone Regional Specialized Meteorological Centres (RSMCs) together with four Tropical Cyclone Warning Centres (TCWCs) established by the World Meteorological Organization (WMO).

Warmer ocean temperatures provide more energy for tropical cyclones, resulting in more intense storms with greater cumulative damage (Chung et al., 2021; Zarzycki et al., 2024). This includes more severe damage from very intense storms (Category 4 and 5) with destructive winds, higher storm surges, and more extreme rainfall. Additionally, a warmer atmosphere can hold more moisture, leading to heavier rainfall during tropical cyclones (Walsh et al., 2016). Rising sea levels can amplify the impact of storm surges, allowing them to reach further inland and cause more widespread flooding (Zarzycki et al., 2024; United States Congress, 2006).

The Tropical Cyclon evolution, path, and intensity can change rapidly, so preparing for the exact impact is challenging. The Tropical Cyclones can spread across borders, affecting multiple countries. The disaster is complex in preparedness and response - communities secure homes and evacuate vulnerable areas. Cyclones can disrupt essential services such as healthcare and public safety, and after the storm, efforts focus on restoring infrastructure and providing temporary housing, followed by long-term recovery. The economic and social impacts can last for years (Lee et al., 2012; UNDRR, 2015). However, they are not categorized as high-impact low-probability risks.
Droughts are identified as a cross-border risk due to their cascading impacts across economic sec-

46 WMO, "Characteristics of tropical cyclones," 2023, available at https://wmo.int/content/characteristics-of-tropical-cyclones

tors, systems, and regions. They are also considered an emerging risk, as their complexity, coupled with increasing frequency and severity driven by climate change, makes their impacts challenging to assess and characterise. As a climate-related risk, droughts are strongly influenced by climate change, with projections indicating more frequent and severe events in Europe due to changes in precipitation, evapotranspiration, and soil moisture. Furthermore, droughts are classified as a high-impact low-probability risk because of their potential for widespread and protracted impacts on agriculture, water supply, energy, ecosystems, and public health, as well as their ability to disrupt national governance and trigger international crisis response mechanisms (Rossi et al., 2024).

Wildfires are a cross-border risk, and classified as an emerging risk due to their unpredictable nature. They are also a climate-related risk, but not considered a high-impact low-probability risk.

Loss, damages, and potential impacts

Heatwave	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		Medium	
Potential impact (next 10 years)	High		Medium	

Heatwaves have caused significant **losses and damages**, both direct and indirect, with wide-ranging economic and non-economic impacts. Direct effects include substantial health consequences, such as fatalities-84,071 deaths in the EU+UK between 1981-2016 (averaging 2,272 annually) (Feyen et al., 2020), and between 55,000 and 72,000 deaths in 2003, 2010, and 2022 due to heatwaves (Copernicus Climate Change Service, 2024). Globally, heat-related deaths averaged 489,000 annually from 2000-2019 (Zhao Q. et al., 2021). Economic damages include increased energy demand for cooling systems, crop losses, and ecosystem degradation. Indirect impacts include surging energy prices, exacerbated droughts, intensified wildfires, loss of income, and the spread of tropical diseases.

Looking ahead, **potential impacts** are projected to worsen with global warming: annual heat-related fatalities could rise from current levels to 30,000 at 1.5°C warming, 52,000 at 2°C, and 96,000 at 3°C by 2100 (Feyen et al., 2020). The rise in human exposure to and fatalities from extreme heat is most pronounced in southern European countries and the highest number of fatalities will occur in France, Italy and Spain. Indirect future impacts mirror current trends but may intensify due to higher electricity consumption and associated challenges (Davis et al., 2015). Heat-related mortality in 800 locations across 50 countries/areas will increase by 0.5%, 1.0%, and 2.5%, respectively; among which 1 in 5 to 1 in 4 heat-related deaths can be attributed to population aging (Chen et al., 2024).

Data collection:

- MunichRe. NatCatSERVICE[47]
- EM-DAT (Delforge et al., 2025);
- National Weather Service;[48]
- Zhao Q. et al. (2021);
- Copernicus Climate Change Service[49]

47 Munich Re. NatCatSERVICE: The Natural Catastrophe Loss Database. *https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html*

48 National Weather Service: *https://www.weather.gov/hazstat*

49 Copernicus Climate Change Service: *https://climate.copernicus.eu/esotc/2023/extreme-weather-and-human-health*

Level uncertainties: Low

Cold wave	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low		Low	
Potential impact (next 10 years)	Low		Low	

Cold waves have caused significant **losses and damages**, primarily in terms of health impacts. Between 1980 and 2017, 3,980 fatalities were recorded across 365 cold wave events in the UK and EU, highlighting the severe risks to human life during such events (Feyen et al., 2020).

Potential impacts of convective storms are wide-ranging. High winds can cause structural damage to buildings, uproot trees, and create flying debris, posing risks to human safety and causing further damage. Flooding causes significant water damage to buildings, infrastructure damage, and soil erosion, disrupting transportation and emergency response efforts. Hail can cause significant structural damage to roofs, siding, windows, vehicles, and agricultural fields, causing significant repair costs and economic losses for farmers. Torna-does can cause complete destruction of buildings, infrastructure damage, and scattered debris fields, complicating cleanup and recovery efforts. Lightning can ignite wildfires, cause structural damage, cause power outages, and pose a direct threat to human safety. Pyrocumulonimbus clouds, formed from the intense heat of large wildfires, can create significant atmospheric changes. These clouds can produce rain, potentially extinguishing the fire, but also generate lightning and powerful winds, increasing the fire's in-tensity and spreading it to new areas. Covective storms can cause business disruptions and agricultural losses, impacting local and national economies, causing indirect impacts such as food shortages and in-creased prices.

Data collection: Faiella et al. (2019) provide an overview of good practices and challenges in current loss and damage da-ta management

- EM-DAT (Delforge et al., 2025);
- Emergency Response Coordination Centre (ERCC) portal[50]

Level uncertainties: Low

Convective storm	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Convective storms cause significant **losses and damages**, both direct and indirect. Direct impacts include physical destruction of property, infrastructure, buildings, and vehicles. In the U.S., severe convective storms have resulted in substantial losses over the past decade, with average annual insured losses nearly equal to those from hurricanes (Geiger et al., 2017c). Indirect impacts include economic consequences such as business interruptions, supply chain disruptions, and loss of productivity due to the destruction caused by these storms.

Potential impacts Potential impacts of convective storms are wide-ranging. Direct effects include structural damage to buildings from high winds, flooding-related water damage and soil erosion, hail damage to roofs, vehicles, and crops, and complete destruction of buildings caused by tornadoes.

50 ERCC portal *https://erccportal.jrc.ec.europa.eu/*

Lightning can ignite wildfires, cause structural damage, and disrupt power supplies, while pyrocumulonimbus clouds formed by large wildfires can intensify fires through lightning and strong winds. Indirect potential impacts include business disruptions, agricultural losses leading to food shortages, and increased prices that affect local and national economies.

Data collection: Data collection: Good practices and challenges of current loss and damage data management: https://www.lodeproject.polimi.it/wp-content/uploads/2020/11/Deliverable_D2.2_LAST_VERSION.pdf

- EM-DAT;
- ERCC portal

Level uncertainties: N/A

Tropical cyclone	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Tropical cyclones cause significant **loss and damages**, for example it may result in infrastructure damage, including destruction of buildings, roads, bridges, power lines, water systems, hospitals, and airports, disrupting transportation, emergency response, and supply chains, posing public health crises. Indirect losses and damages include the disruption of business operations, supply chains, and long-term economic impacts, along with increased unemployment and community displacement, significant social consequences.

Tropical cyclones can cause severe **potential impacts** through heavy rain, strong winds, and storm surges. Heavy rainfall can lead to flash floods, river floods, urban flooding, landslides, mudslides, agricultural damage, and water contamination resulted in substantial property and life loss. Strong winds are highly destructive, damaging structures, power poles, communication systems, and buildings, leading to injuries, fatalities, and property loss. Storm surges can cause extreme coastal and inland flooding, property loss, beach erosion, damage to coastal habitats and infrastructure, and fatalities[51]. Tropical cyclones can cause secondary effects like landslides, power outages, fires, transport disruptions, infrastructure damage, and livestock loss. They can also cause water-borne diseases from flooding, which can persist long after the cyclone, threatening human life and the economy. Long-term economic challenges include food price spikes and loss of livelihoods (UNDAC, 2024, chapter K.3.4).

Data collection:

- Impact on Insured Losses from Swiss Re Institute (Swiss Re Institute, 2024),
- WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019) (WMO, 2021),
- A data collection of tropical cyclone exposure data sets (TCE-DAT) (Geiger et al., 2017),
- A global data set of tropical cyclone exposure (TCE-DAT) (Geiger et al., 2017),
- A global data set of spatially-explicit tropical cyclone exposure (TCE-DAT) (Geiger et al., 2017)
- Global Disaster Alert and Coordination System (GDACS)[52]

Level uncertainties: High

51 WMO Fact sheet. Characteristics of tropical cyclones, 20 Sep 2023: *https://wmo.int/content/characteristics-of-tropical-cyclones*

52 GDACS: *https://www.gdacs.org/*

The modelling of the potential impacts of tropical cyclone is complex and influenced by factors such as climate model choice, emission scenarios, and socio-economic development pathways. The choice of climate model significantly affects output uncertainty. The emission scenarios for future tropical cyclone projections shapes the distribution of tropical cyclone risk change estimates much less than the global climate model choice. When considering the two drivers of climate change and socio-economic development (population growth and economic changes factors that influence the exposure and vulnerability of populations and assets to tropical cyclones) together the uncertainty associated with future tropical cyclone risk projections increases non-linearly (Meiler et al., 2023). Different CMIP6 (the sixth phase of the Coupled Model Intercomparison Project) climate models simulations reveal significant discrepancies in the frequency and intensity projections of North Atlantic tropical cyclone activity, indicating a high level of uncertainty in modelling its potential impacts (Xi et al., 2024). The inherent variability of physical processes, such as vertical wind shear and atmospheric moisture, further contributes to uncertainty in the prediction of cyclone intensity and frequency (Fosu et al., 2024). In a short-term forecast, the key challenges remain, particularly in predicting storm intensity, and the exact location of the tropical cyclone landfall as small atmospheric changes can greatly affect forecasts. The most unpredictable storms occur in environments with moderate vertical wind shear and humidity (National Oceanic and Atmospheric Administration's (NOAA) Atlantic Oceanographic and Meteorological Laboratory, 2024).

Drought	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium		High	
Potential impact (next 10 years)	High		High	

Droughts have caused substantial **losses and damages** across nearly all regions of the European Union, significantly impacting critical systems such as agriculture, water supply, energy, river transport, and ecosystems. These impacts result in estimated annual losses of around €9 billion. Indirect effects can manifest with delays and through teleconnections, negatively affecting areas far from the drought's origin. However, these indirect impacts are often not fully tracked or considered, thus leading to underestimating the total damages (Rossi et al., 2024).

Droughts are projected to increase in frequency and severity in Europe over the next decades, with significant **potential direct impacts** on sectors such as agriculture, water supply, energy, river transportation, and ecosystems. Indirect potential impacts include cascading and systemic effects such as business interruptions, economic losses, and social consequences, which can be substantial and far-reaching. Teleconnections may also amplify these effects by negatively impacting regions distant from the drought's origin, further swelling the overall estimates of damage (Rossi et al., 2024).

Data collection:

- EDID
- EDRA

Level uncertainties: Medium to high

There are several sources of uncertainty in modelling the potential impacts of droughts, including:

1. Uncertainty in climate projections: There is uncertainty in climate projections, including the magnitude and timing of changes in temperature and precipitation
2. Uncertainty in hydrological modelling: There is uncertainty in hydrological modelling, including the representation of complex hydrological processes and the estimation of model parameters
3. Uncertainty in agricultural modelling: There is uncertainty in agricultural modelling, including the representation of crop growth and yield responses to drought as well as the representation of

evolving agro-management strategies

4. Uncertainty in economic modelling: There is uncertainty in economic modelling, including the estimation of economic losses and the representation of economic systems
5. Uncertainty in social and behavioural modelling: There is uncertainty in social and behavioural modelling, including the representation of human behaviour and decision-making under drought conditions

These sources of uncertainty can lead to a range of possible outcomes, making it challenging to predict the exact impacts of droughts. Therefore, the level of uncertainty in modelling the potential impacts of droughts is medium to high (Rossi et al., 2024).

Wildfires	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Data collection: European Forest Fire Information System (EFFIS)[53]

Level uncertainties: Medium

It is known that wildfires will occur but there is uncertainty on the number/extent, distribution of wildfires and their intensity.

Risk drivers and interactions

Heatwave

Risk drivers	• Climate change; • Environmental degradation; • Urbanisation; • Demographical developments
Hazards triggering	• Drought
Hazards triggered by	• Drought; • Wildfires; • Storms; • Air pollution
Cascading impacts	• Electricity demand overstretch; industry disruption (depending on cooling); in-creased emissions (Davies et al., 2015) • ecosystems degradations
Compound relationships	• Drought;[54] • Wildfires; • Storms; • Tropical Cyclones

53 EFFIS: *https://forest-fire.emergency.copernicus.eu/*

54 Europe 2022 combined heatwave and drought, *https://www.copernicus.eu/en/news/news/observer-wrap-europes-summer-2022-heatwave*

Cold wave

Risk drivers	• High land albedo (e.g. snow); • Aerosol reflection
Hazards triggering	N/A
Hazards triggered by	N/A
Cascading impacts	• Infrastructure stress; • blackouts; • crop failure, etc. • economic costs (maintenance, consumer costs) • increase pollution and emissions • higher agricultural prices
Compound relationships	• snow & ice storms; • wind-storms (blizzards)

Convective storm

Risk drivers	• Climate change • urbanisation, • demographic developments (population growth, migration, socio-economic changes), • Deforestation and environmental degradation, • globalisation, • political instability, • technological developments.
Hazards triggering	• Extreme weather conditions (indirect)
Hazards triggered by	• Tornadoes, • Large hail (Hailstones - 2.5 cm), • Hail swaths (large areas of hail on the ground), • Damaging winds (wind gusts ≥ 93 km/h), • Flash flooding (heavy rainfall), • Lightning, • Wildfires (especially in dry areas), • Dust storms, • Convective downdrafts (can cause aircraft to lose altitude and crash), • Long-lived, straight-line wind storms (*derechos*), • Pyrocumulonimbus clouds
Cascading impacts	• Landslides and mudslides (from heavy rainfall), • Power outages (from strong winds and lightning), • Transportation disruptions (from heavy rainfall, hail, and strong winds), • Structural damage (from strong winds and hail).
Compound relationships	• Lightning, Large Hail, Severe Wind, Tornadoes[55]

55 Severe Convective Storms across Europe and the United States. Part I: Climatology of Lightning, Large Hail, Severe Wind, and Tornadoes *https://journals.ametsoc.org/view/journals/clim/33/23/jcliD200345.xml*

Tropical cyclone

Risk drivers	• Climate change; • Urbanisation; • Demographical developments; • Environmental degradation; • Globalisation; • Geopolitical developments; • Technological developments; • *Political instability and conflicts* can hinder disaster response and recovery efforts. • *Advances in technology* can enhance preparedness, but reliance on it can increase vulnerability
Hazards triggering	• Extreme weather conditions (indirect)
Hazards triggered by	• Floods; • Coastal floods; • Landslides; • Diseases outbreak; • Storm surges; • Tornadoes; • Disruption of essential services; • Soil erosion; • Fires (as result of power damage);
Cascading impacts	• disruption of essential services; • power outage • destruction of buildings and road blockages; • water contamination; • crop loss and food shortage; • salt water intrusion that can lead to long term displacement, economic losses and significant re-building losses);
Compound relationships	• tropical cyclone and flooding • flooding and landslides; • Heavy rainfall and flash flooding • Cyclone followed by heatwave, can lead to increase in water-borne disease.

Drought

The analysis below for droughts is based on the European Drought Risk Atlas (Rossi et al, 2024).

Risk drivers	• Climate change; • Environmental degradation; • Water management practices; • Socio-economic factors
Hazards triggering	• Heatwaves
Hazards triggered by	• Wildfires, • Flash floods, • Water scarcity
Cascading impacts	• Disruption of essential services (water supply) • Ecosystem degradation, • Economic disruption, • Energy shortages, • Soil erosion and land degradation, • Food insecurity
Compound relationships	• Heatwaves, • Wildfires, • Floods, • Storms, • Landslides

Wildfires

Risk drivers	• Climate change; • Urbanisation; • Environmental management
Hazards triggering	N/A
Hazards triggered by	• Natech, • Health hazards (air pollution), • Soil erosion, • landslides, • water pollution
Cascading impacts	• Health respiratory issues, • loss of ecosystem services (soil protection, water purification) • Disruption of essential services (water supply)
Compound relationships	N/A

Gaps and needs

	Operational	Research	Policy
Heatwave	Dedicated sectoral reporting schemes for heatwave damage/loss are lacking; Unified methodologies for conducting hazards, exposure, vulnerability, and risk assessments are needed; Standardised formats for data preparation and communication of results are missing	Comprehensive epidemiology of heatwaves is needed standards for heatwave risk assessments and reporting are missing;	National guidelines for heatwave risk assessments and reporting are missing (urgent); Adaptation strategies for vulnerable people are not in place
Cold wave	No significant gaps		
Convective storm	N/A		
Tropical cyclone	Capacity gaps in national and local disaster risk management systems; (Munsaka et al., 2021)	Need for standardised methodologies for risk assessment; (APDIM, 2021)	Need for stronger disaster legislation and policy to provide a framework for DRM; Need for national guidelines or standards to provide unified methodologies for conducting risk assessments; (APDIM, 2021) Need for improving disaster risk governance capabilities in a changing climate by building adaptive recovery programs (UNDP, 2015)
Drought	Data limitations: Accuracy, availability, and standardisation of data hinder effective drought risk management (Rossi et al., 2024).	Methodological gaps: Insufficient protocols, standards, and scientific literature impede comprehensive understanding and management of drought risk (Rossi et al., 2024).	Understanding and reporting: Limited understanding of drought risk and lack of standardised impact reporting hinder effective decision-making and communication (Rossi et al., 2024).
Wildfires	Wildfire behaviour models in use in Decision Support Systems	Understanding fuel-atmosphere interaction, predicting explosive fire behaviour, and developing wildfire behaviour models in urban-wildfire interfaces.	Planning for wildland-urban-interface (WUI) wildfires; Implementation of existing policies in the WUI (existing policies are difficult to implement or verify on the ground).

Policy references and adaptation/mitigation measures

Heatwave

Adaptation measures in place	Weather advisories (both commercial and public service), official bulletins by met offices and civil protection, including warnings and dissemination; Civil protection support: public awareness campaigns, warning dissemination and prevention activities, response and support for vulnerable people Insurance schemes; Technological solutions (e.g. heat-tolerant crops, insulation of buildings, etc.) Urban greening (both as mitigation and adaptation measure)"
Recommended adaptation measures	Further strengthening of the measures already in place
Mitigation measures in place	Indirectly all policies against Greenhouse gases and climate change;
Recommended mitigation measures	Indirectly, climate change mitigation initiatives and actions; Decreasing the heat island effect in urban areas (e.g. greening, increasing albedo, ...)
Policy references	UN EW4All[56]; UCPM Decision No 1313/2013/EU revision Decision (EU) 2019/420 (European Parlia-ment and Council, 2019a) Heat Action Plans and Case Studies[57] Heat-health action plans and surveillance[58] UNDRR Hazard Information Profile on heatwave[59] United Nations Framework Convention on Climate Change (UNFCCC) (UN General As-sembly, 1992). Sendai Framework for Disaster Risk Reduction (UNDRR, 2015). United Nations Framework Convention to Combat Desertification (UNCCD, 1994).

Cold wave

Adaptation measures in place	Weather advisories; technological solutions (e.g. insulation systems, crop tolerance to low-temperatures, etc.); Insurance schemes;

56 https://www.undrr.org/implementing-sendai-framework/sendai-framework-action/early-warnings-for-all

57 https://ghhin.org/heat-action-plans-and-case-studies/

58 https://climate-adapt.eea.europa.eu/en/observatory/evidence/heat-health-action-planning-surveillance

59 https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0047

Recommended adaptation measures	Further strengthening of the measures already in place
Mitigation measures in place	Due to climate change, with an overall increase of temperatures, the chance of cold waves tends to decrease overall, and therefore may be considered as a mitigation factor to this risk.
Recommended mitigation measures	N/A
Policy references	EW4All[60] and any other general climate/weather initiatives or policies, cold waves do not attract much attention at the moment. At national or sub-national level, it may vary.

Convective storm

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	N/A
Recommended mitigation measures	N/A
Policy references	N/A

Tropical cyclone

Adaptation measures in place	The National Hurricane Program (NHP) is a joint effort between the Federal Emergen-cy Management Agency (FEMA), NOAA's National Hurricane Center, and the U.S. Army Corps of Engineers, aiming to manage tropical cyclone risks by providing planning tools, evacuation training, and real-time guidance. It covers eight key areas, including hazard analysis, evacuation studies, decision support tools, training, operational sup-port, coordination, technology integration, and post-storm assessment (National Hurri-cane Program Technology Modernization Working Group, 2017). The National Disaster Management Guidelines - Management of Cyclones (India) points adaptation measures that are currently in place for tropical cyclone risk in India and include early warning systems, cyclone shelters, and structural measures such as buildings, road links, culverts, and bridges designed to withstand cyclones. Additionally, there is a National Cyclone Risk Mitigation Project (NCRMP) which include components such as improvement of early warning dissemination systems, cyclone risk mitigation investments, technical assistance for hazard risk management and capacity-building, and project management and institutional support (National Disaster Management Au-thority, 2008).

60 https://www.undrr.org/implementing-sendai-framework/sendai-framework-action/early-warnings-for-all

Recommended adaptation measures	Effective disaster management requires collaboration across various fields. This includes atmospheric sciences, engineering, urban planning, and public health. Infrastructure improvements, community-level actions, and technological advancements are crucial for effective risk assessment and management. Special attention is needed for marginalized groups, such as the homeless, disabled, and undocumented migrants. They are at higher risk during disasters. It is necessary to focus efforts on both immediate recovery and long-term sustainability (Shultz et al., 2018).
Mitigation measures in place	Measures like technical assistance to state, local, and tribal governments for evacua-tion preparedness, including preparing evacuation studies, developing evacuation plans, assessing storm surge estimates, assessing transportation and shelter capacity (Na-tional Hurricane Program Technology Modernization Working Group, 2017). Mitigation structural measures include building cyclone-resistant structures, road links, culverts, bridges, canals, drains, surface water tanks, saline embankments, communi-cation and power transmission networks, while the non-structural measures include early warning systems, communication, coastal zone management, awareness genera-tion, and disaster risk management (National Disaster Management Authority, 2008).
Recommended mitigation measures	Diversifying livelihoods (support livelihoods that are less vulnerable to cyclones - eco-tourism, aquaculture, or agriculture that is not heavily reliant on coastal resources), implementing robust flood protection measures (sea walls, levees, or flood gates, to prevent storm surges and flooding in coastal areas), promoting green infrastructure (wetlands, mangroves, and dunes, to mitigate the impact of cyclones), developing advanced early warning systems (timely, accurate and reliable warnings to communities at risk), supporting community-based initiatives (training programs, awareness campaigns, and community-led projects that empower local residents to take action), ensuring critical infrastructure is designed to withstand extreme weather events (power plants, hospitals, and emergency services that meet cyclone-resistant standards), promoting ecosystem-based adaptation (restoring degraded ecosystems, promoting sustainable land use practices, and conserving biodiversity), promoting cyclone-resistant construction (use of reinforced materials, storm shutters, and impact-resistant windows), promoting flood-resilient agriculture practices (flood-tolerant crops, agroforestry, and conservation agriculture), enhancing international cooperation (collaborating with other countries, international organizations, and research institutions to share best practices, technologies, and expertise), and integrating cyclone risk reduction and management into broader climate change adaptation strategies (financial support to communities affected by cyclones, assessing the impacts of climate change on cyclone risk, developing climate-resilient infrastructure, and promoting climate-smart agriculture practices) (Drishti IAS, 2023).

Policy references	EW4All; UCPM Decision No 1313/2013/EU revision Decision (EU) 2019/420 (European Parliament and Council, 2019a); Sendai Framework for Disaster Risk Reduction (2015–2030); The Disaster Management Act, 2005, from the Government of India. Tropical cyclone disaster risk management aims to minimise losses in lives, livelihoods, health, and assets by understanding risks, strengthening governance frameworks, and investing in risk reduction measures. Enhancing preparedness is crucial for effective response and post-disaster recovery. This comprehensive approach builds resilience and minimise the impact of tropical cyclones on communities (UNDRR, 2015). Integrated multi-sectorial Communication for Development (C4D) interventions into the humanitarian response to the disaster, including a risk communication and community engagement (RCCE) plan to promote life-saving services and interventions (RCCE Collective, 2022). The Disaster Management Act, 2005 is a key policy reference in India for managing disaster risks. It establishes a comprehensive framework for disaster management across three levels: National, State, and District (Government of India, 2005).

Drought

Adaptation measures in place	Water conservation measures, Drought management plans, Sustainable land use and management practices, Early warning systems
Recommended adaptation measures	Water harvesting, water reuse, Soil conservation, Efficient irrigation systems, Climate-resilient infrastructure and landscape, sustainable use and management of land and water resources, water efficiency, proactive and prospective drought management, risk-oriented early waring systems and tailored climate services
Mitigation measures in place	Implement water-saving technologies and actions to reduce water demand; Develop and implement drought management plans that outline strategies for increasing the preparedness and mitigating the impacts of droughts; Promote sustainable land use practices, such as agroforestry and conservation agriculture, to enhance socioeconomic and ecosystem resilience to droughts; Invest in nature-based solutions and sustainable water storage infrastructure to increase the resilience during periods of drought;
Recommended mitigation measures	Reduce greenhouse gas emissions to slow the rate of climate change and reduce the risk of droughts; Implement efficient and sustainable irrigation systems and policies to reduce water consumption and optimize water use and water re-use; Restore and protect natural ecosystems, such as wetlands and forests, to maintain ecosystem services and reduce the risk of droughts; Support the implementation of nature-based solutions, climate resilient landscape, and climate-resilient infrastructure development, such as climate-resilient water infrastructure, to reduce the vulnerability of communities to droughts; proactive and prospective drought risk management plans. Develop and implement policies and actions across scales to enhance water efficiency and avoid concurrent peaks in demand.

Policy references	EU's Water Framework Directive (2000/60/EC) (European Parliament and Council, 2000); EU's Floods Directive (2007/60/EC) ((European Parliament and Council, 2000); EU's Climate Change Adaptation Strategy (European Commission, 2021); EU's Common Agricultural Policy (CAP) (European Commission, 2025a); EU's Drinking Water Directive (98/83/EC) (European Parliament and Council, 1998);

Wildfires

Adaptation measures in place	None in place at EU level
Recommended adaptation measures	Nothing specific at EU level
Mitigation measures in place	Nothing specific at EU level; recommendation for education & awareness campaigns for reduction of fire ignitions, recommendation for fuel management to reduce wildfire spread and intensity
Recommended mitigation measures	UCPM in support to firefighting
Policy references	No specific policy on wildfires. Related policies: Rural Development Regulation (CAP) (European Parliament and Council, 2021); EU Climate Change Adaptation Strategy (European Commission, 2021); EU Forest Strategy (European Commission, 2018); EU Biodiversity Strategy (European Commission, 2020b); Nature Restoration Law (Regulation (EU) 2024/1991) (European Parliament and Coun-cil, 2024i); Forest Monitoring Framework (COM(2023)728) (European Commission, 2023b); EU Solidarity Fund (Regulation (EC) No 2012/2002) (Council of the European Union, 2002); EU Civil Protection Mechanism (Decision No 1313/2013/EU) (European Parliament and Council, 2013, as amended)

Hydrological

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Floods	Yes	Yes	Yes	Yes
Coastal floods	Yes	Yes	Yes	Yes

Floods can be considered a cross-border risk because they often affect multiple countries, especially in regions with shared river basins. Heavy rainfall or upstream flooding in one nation can lead to sig-

nificant impacts downstream, resulting in economic disruptions, humanitarian crises, and the need for coordinated international response efforts. Floods are considered an emerging risk due to changes in their frequency, intensity, and impact, influenced by climate change, urbanization, and rising sea levels, which increase uncertainty in their management. Climate scenarios in risk assessment are relevant (Feyen et al., 2020). Floods are typically classified as a high impact, low probability risk in certain regions and contexts. In many locations, the likelihood of a major flooding event is relatively low and when such events do occur, the consequences can be catastrophic. However, the increasing effects of climate change are altering this dynamic and the frequency and intensity of extreme flood events, are becoming more pronounced. Consequently, even regions that historically experienced low flood risk may now face more frequent and severe flooding. This escalation can lead to even greater damages, as communities may not be adequately prepared for the sudden onset of extreme flooding events.

In summary, while floods have traditionally been viewed as a high impact, low probability risk, the influence of climate change is reshaping this perception, leading to more frequent and devastating flooding occurrences.

Increasing **coastal flood** and erosion intensity and frequency from sea level rise is a cross-border risk because:

i. rising seas will increase flood risk everywhere;

ii. oastal floods may take place locally but come with broader spill over effects, especially when critical infrastructure is affected.

The zones in Europe that are more affected by sea level rise include low-lying areas and coastal zones, particularly in the Mediterranean Sea basin.

Coastal erosion and floods are not new risks, but sea level rise functions as a risk multiplier. Extreme events that now are expected once in 100 years will become 10 to 100 times more frequent (once in 1-10 years), from 2050 and onwards. Unless timely adaptation measures are taken, such an increase in frequency will challenge our economies, environment and wellbeing in unprecedented ways. Climate change is expected to have significant impact on sea level rise.
The following factors should be considered:

- Sea level rise projections: Based on different climate scenarios and emission pathways
- Extreme sea levels: Including storm surges, tidal waves, and other extreme events
- Coastal erosion and flooding: Due to sea level rise, storm surges, and other coastal processes
- Saltwater intrusion: Into freshwater sources and ecosystems
- Impacts on human settlements and infrastructure: Including damage to buildings, roads, and other infrastructure
- The potential trends based on different climate scenarios are as follows:
- RCP2.6 (low-emissions scenario): Sea level rise is projected to be around 0.26-0.55 m by 2100, with a likely range of 0.17-0.43 m
- RCP4.5 (medium-emissions scenario): Sea level rise is projected to be around 0.32-0.63 m by 2100, with a likely range of 0.22-0.51 m
- RCP6.0 (medium-high-emissions scenario): Sea level rise is projected to be around 0.36-0.71 m by 2100, with a likely range of 0.25-0.59 m
- RCP8.5 (high-emissions scenario): Sea level rise is projected to be around 0.45-0.82 m by 2100, with a likely range of 0.32-0.69 m28

Loss, damages, and potential impacts

Floods	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Data collection:

- EM-DAT (Delforge et al., 2025);
- Munich Re. NatCatSERVICE[61]
- HANZE (Paprotny et al, 2024)

Level uncertainties: High

Flood risk is associated with a high level of uncertainty, due to several interrelated factors:

- Limitations in climate and hydrological modelling: Future projections of extreme rainfall and river discharge carry significant uncertainty, especially at local and regional scales, due to natural variability and modelling limitations.
- Lack of harmonised data across countries: At the European level, differences in data availability, collection methodologies, and definitions make it difficult to ensure consistency and comparability in flood risk assessments.
- Complexity of compound and cascading events: Floods frequently interact with other hazards, such as coastal surges or landslides, amplifying their impacts and complicating both modelling and response planning.

Coastal floods	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Medium	Medium
Potential impact (next 10 years)	Medium to high	Medium to high	Medium	Medium

Coastal floods have caused significant direct and indirect **losses**, both economic and non-economic. Direct economic losses include damages such as those from the "Big Flood" of 1953, which caused over €2 billion in damages (in today's prices) and resulted in the loss of 2,190 lives across the Netherlands, Belgium, England, and Scotland (Gerritsen, 2005; McRobie et al., 2005). Current expected annual direct damages from coastal floods are estimated at €1.2 billion (Feyen et al., 2020). Direct non-economic losses include injuries, loss of lives, damage to ecosystems, cultural heritage, and historical sites, as well as lifestyle changes and loss of beach amenity value due to erosion. Indirect economic impacts include business interruptions, decreased productivity, supply chain disruptions, relocation costs, and adaptation expenses. Indirect non-economic impacts encompass displacement of communities, loss of cultural heritage and traditional knowledge, psychological trauma, and decreased quality of life.

The **potential impacts** of coastal floods are expected to escalate significantly with global warming. Direct economic damages from sea level rise are projected to increase disproportionately, rising from €1.3 billion annually today to €13–39 billion by 2050 and €93–960 billion by 2100 under various

61 Munich Re. NatCatSERVICE: The Natural Catastrophe Loss Database. *https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html*

scenarios (Vousdoukas et al., 2018; Feyen et al., 2020). Direct non-economic impacts are anticipated to follow similar patterns as present-day impacts but could increase by 1–2 orders of magnitude depending on future scenarios. Indirect economic effects could include further disruptions to trade and supply chains, while indirect non-economic effects may involve greater displacement of communities and loss of cultural heritage.

Data collection:

- LISCOAST[62]
- Permanent Service for Mean Sea Level (PSMSL)[63]
- Copernicus Marine Service[64]
- NOAA Sea Level Rise Database[65]
- IPCC Sea Level Rise Database[66]
- GESLA (Global Extreme Sea Level Analysis)[67]
- SONEL (Système d'Observation du Niveau des Eaux Littorales)[68]
- EMODnet (European Marine Observation and Data Network)[69]

Level uncertainties: Medium to high

The level of uncertainties are related to:

- Imprecision in data
- Ambiguously defined concepts or terminology
- Incomplete understanding of critical processes
- Uncertain projections of human behaviour
- Model uncertainty
- Scenario uncertainty
- Downscaling uncertainty

To address these uncertainties, the report recommends:

- Improve data collection and monitoring;
- Advance modelling and simulation;
- Use expert judgment and stakeholder engagement;
- Develop robust decision-making frameworks.

62 Data Catalogue of the JRC: *https://data.jrc.ec.europa.eu/collection/liscoast*

63 Global sea level data from tide gauges and other sources, showing trends and variability. *https://psmsl.org/*

64 Sea level data from satellite altimetry and other sources, showing trends, variability, and extreme events. *https://marine.copernicus.eu/register-copernicus-marine-service*

65 Sea level data from tide gauges and other sources, showing trends and variability *https://oceanservice.noaa.gov/hazards/sealevelrise/*

66 Sea level data providing information on trends, variability, and projections. *https://ipcc-browser.ipcc-data.org/*

67 Extreme sea level data and trends from tide gauges and other sources.*https://gesla787883612.wordpress.com/*

68 Sea level data from tide gauges and other sources, showing trends and variability.*https://www.sonel.org/*

69 Sea level data providing information on trends, variability, and extreme events. *https://emodnet.ec.europa.eu/en*

Risk drivers and interactions

Floods

Risk drivers	• Climate change; • Urbanisation; • Environmental degradation; • Infrastructure failure
Hazards triggering	• Heavy Rainfall; • Snowmelt; • Storm surges; • Tropical cyclones and Hurricanes; • Dam breaks/levee failure.
Hazards triggered by	• landslides; • waterborne diseases; • infrastructure damage; • economic disruption; • loss of habitat or biodiversity
Cascading impacts	• Disruption of essential services (water supply) • Disruption of supply chains; • Displacement of Communities; • Loss of agricultural productivity; • Increased Risk of waterborne diseases; • Long-term environmental damage; • Psychological impacts
Compound relationships	• Landslides; • Water contamination; • Heatwave and droughts; • Infrastructures failure;

Coastal floods

Risk drivers	• Climate change; • Urbanisation; • Environmental degradation; Subsidence;
Hazards triggering	• Sea level rise; • Waves; • Storm surge
Hazards triggered by	• Coastal erosion; • Flooding; • Saltwater intrusion;
Cascading impacts	• Disruption of essential services (water supply) • Economic disruption; • Social disruption; • human health impacts; • loss of ecosystem services;

Compound relationships	• Storm surges • Heavy rainfall[70] • Flooding from rivers

Gaps and needs

	Operational	Research	Policy
Floods	Data and Monitoring: Inadequate data collection and limited real-time monitoring systems for flood forecasting; Early Warning Systems: Lack of robust early warning systems to alert communities about impending flood events. Community Awareness: Developing effective public awareness and education programs on flood risks and preparedness measures.	Data Analysis: Improving data collection and analysis to better understand flood risks and inform planning and response.	Integrated Planning: Insufficient integration of flood risk management into land use planning and environmental policies; Resource Allocation: Inadequate funding and resources for disaster response and recovery efforts.
Coastal floods	Data accuracy and missing data: Gaps in data availability and accuracy hinder risk assessment and management; Limited stakeholder engagement: Inadequate engagement of stakeholders leads to ineffective solutions	Gaps in methodology: Limitations in current methodologies lead to inaccurate risk assessments; Gaps in scientific literature: Insufficient research on certain aspects of sea level rise limits effective risk management strategies	Lack of protocols/standards: Absence of standardized guidelines for sea level rise risk assessment and management; Lack of international cooperation: No coordinated global efforts to address sea level rise; Inadequate funding and resources: Insufficient funding limits implementation of effective risk management measures.

70 In low-lying coastal areas, the co-occurrence of high sea level and precipitation resulting in large runoff may cause compound flooding (CF). When the two hazards interact, the resulting impact can be worse than when they occur individually (Bevacqua et al., 2019).
The concurrence or short succession of these two hazards can cause compound flooding that can result in larger impacts than would be caused by the individual hazards acting alone, as exemplified by recent events in the Shoalhaven estuary (Australia, 2016), Ravenna (Italy, 2015), Cork (Ireland, 2009), and Lymington (United Kingdom, 1999) (Bevacqua et al., 2020)

Policy reference and adaptation/mitigation measures

Floods

Adaptation measures in place	flood risk management plans; nature based solution; urban planning; financial support and investments; research
Recommended adaptation measures	Enhancing Nature-Based Solutions; integrating climate adaptation into urban planning; community involvement and education; policy and governance enhancements; investment in infrastructure resilience
Mitigation measures in place	flood defences and retention basins; land use planning; public awareness campaign; insurance; early warning system
Recommended mitigation measures	Strengthening and encouraging the one already in place
Policy references	EU's Water Framework Directive (2000/60/EC) (European Parliament and Council, 2000); EU's Floods Directive (2007/60/EC) (European Parliament and Council, 2007); EU's Climate Change Adaptation Strategy (European Commission, 2021); EU's Common Agricultural Policy (CAP) (European Parliament and Council, 2021); EU Disaster Risk Reduction Policy (European Commission, 2009); EU Civil Protection Mechanism (European Parliament and Council, 2013, as amended);

Coastal floods

Adaptation measures in place	Sea walls and coastal protection structures; Beach nourishment; Dune restoration; Wetland restoration; Flood-control gates; Elevating buildings and infrastructure; Relocating people and infrastructure; Early warning systems; Climate-resilient water management; Ecosystem-based adaptation;

Recommended adaptation measures	Recommended adaptation measures Ecosystem-based adaptation; Nature-based solutions; Climate-resilient water management; Early warning systems; Flood-control gates; Elevating buildings and infrastructure; Relocating people and infrastructure; Climate-resilient urban planning; Community-based adaptation; Enhanced data collection and monitoring; Stronger regulatory frameworks; Integrated climate adaptation strategies; Investment in research and development; International collaboration; Public awareness campaigns; These measures aim to enhance resilience against sea level rise while addressing the challenges posed by climate change
Mitigation measures in place	Reducing greenhouse gas emissions: The EU's Climate and Energy Framework (Euro-pean Commission, 2020) sets a target to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels; Increasing energy efficiency: The EU's Energy Efficiency Directive (2012/27/EU) (Euro-pean Parliament and Council, 2012) sets a target to reduce energy consumption by 32.5% by 2030 compared to 2007 levels Promoting renewable energy: The EU's Renewable Energy Directive (2018/2001/EU) (European Parliament and Council, 2018) sets a target to increase the share of renew-able energy in the energy mix to at least 32% by 2030; Carbon capture and storage: The EU's CCS Directive (2009/31/EC) (European Parliament and Council, 2009) requires Member States to develop plans for the deployment of carbon capture and storage technology
Recommended mitigation measures	Transitioning to a low-carbon economy; Implementing measures to enhance carbon sinks; Promoting sustainable consumption and production patterns; Implementing climate-resilient infrastructure; Supporting research and development; Investment in Green Technologies; International Collaboration; Enhanced Regulatory Frameworks ; Research and Development;
Policy references	EU Strategy on Adaptation to Climate Change (European Commission, 2021); EU Floods Directive (European Parliament and Council, 2007); EU Marine Strategy Framework Directive (European Parliament and Council, 2008); EU Coastal Zone Management Directive (European Commission, 2002); EU Climate Change Adaptation Policy (European Commission, 2021b); EU Disaster Risk Reduction Policy (European Commission, 2009); EU Environmental Impact Assessment Directive (European Parliament and Council, 2011). These policies aim to reduce the risk of flooding and other disasters related to sea level rise, promote sustainable development and management of coastal zones, and support EU countries in developing and implementing adaptation measures to address the impacts of climate change

Geophysical

Geophysical risks covers three risks: earthquake, tsunami and volcanoes.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Earthquake	Yes	No	No	Yes
Tsunami	Yes	No	Yes	Yes
Volcanoes	Yes	No	No	Yes

Earthquakes are considered a cross-border risk due to their ability to affect multiple regions and countries simultaneously. They are not classified as emerging risks, as they are well-studied and understood. Similarly, earthquakes are not climate-related risks, as their occurrence is not influenced by climate change. However, they are categorized as high-impact, low-probability risks, given their rare occurrence but devastating effects across several sectors and large areas, with both their probability and impact being well-known.

Tsunamis are considered a cross-border risk as their impacts can extend across multiple regions and countries, particularly along coastlines. They are not classified as emerging risks, as they are well-understood phenomena. Additionally, tsunamis are categorised as high-impact, low-probability risks because they occur infrequently but can cause devastating effects over large areas.

Volcanoes are considered a cross-border risk, as more than 50 volcanoes border two countries, but several others are located very close to the country borders. Depending on the typology of the eruption, the volcanic products could impact one or more neighbouring countries.

For example:

i. the ash fall from a huge explosive eruption, could spread for hundreds of kilometres and it could affect a wide area, resulting in a possible hazard to aircraft and public health (e.g. 2010 eruption of Eyjafjallajökull in Iceland);.

ii. Another example, not so common for neighbouring countries, could be related to the pyroclastic flows that are characterized by a high-density mix of hot lava blocks, pumice, ash and volcanic gas which move at very high speed down volcanic slopes, typically following valleys (United States Geological Survey, 2024).

Ash volcanic emission and volcanic ash dispersal in the atmosphere can intrest the entire planet directly changing climate scenario due to long term ash-cloud coverage. They are categorised as high-impact, low-probability risks due to their rare occurrence but potentially devastating effects on affected regions (Bravo-Laguna, 2021).

Loss, damages, and potential impacts

Earthquakes	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Losses and damage are high in a number of EU countries, and medium or low in others (Gkatzogias et al., 2022a). **Future impact** is high in a number of EU countries, and medium or low in others.

Data collection:

- The human cost of disasters: an overview of the last 20 years (2000-2019) (UNDRR and CRED, 2020);
- EU Solidarity Fund Interventions for Natural Disasters 2024 (European Commission, 2024b).

Level uncertainties: Low

Tsunami	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Human and economic losses far outnumber other natural disasters (UNDAC, 2024, chapter K).

Direct impacts and potential impacts include:

- Massive loss of lives;
- Inundation;
- Wave impact on structures
- Erosion collapse (e.g. of buildings, foundations, bridges, seawalls, embankments, railroads,...)
- Strong currents with dangerous floating debris further destroying the exposed environment (e.g. cars, trees, ships...)
- Debris
- Fires resulting from oil spills or combustion
- Power shortages

Indirect impacts and potential impacts include:

- Sewage and chemical pollution following destruction
- Damage to intake, discharge, and storage facilities
- Long-term effects on the environment, agriculture, and fisheries (e.g. due to saltwater which gets deposited on the ground)
- Sediment and coral rubble thrown about by a tsunami can damage coral reefs
- Damage to mangroves can be highly variable, ranging from little damage in some areas to the destruction of entire forests in other areas

When an earthquake that triggers a tsunami occurs near land, the resulting impact can be compounded by typical earthquake damages.

Data collection:

- GDACS;
- EM-DAT (Delforge et al., 2025);
- Euro-Mediterranean Tsunami Catalogue (EMTC) (Maramai et al., 2019a);
- NCEI/WDS Global Historical Tsunami Database (NGDC/WDS, 2025);
- UN-SPIDER/NOAA Global Historical Tsunami Database (NOAA, 2025);
- UNESCO-IOC Tsunami Information Centre (IOC UNESCO, 2025a);
- national databases, e.g. Italian Tsunami Effects Database (ITED) (Maramaiet al., 2019b).

Level uncertainties:

Two of the key tools for tsunami risk mitigation are the probabilistic tsunami hazard maps and the tsunami warning systems. In both cases, the uncertainty of the information -and the consequent decision- is a factor, which cannot be avoided. For example, in the case of a tsunami warning system, due to the vicinity of the tsunami source, sometime the alert needs to be disseminated in the absence of actual confirmation of a tsunami even being ongoing. This difficult decision is sometime taken in favour of safety; however, the public opinion should be fully aware of the validity of such systems, despite the possible false alarms.

Volcanoes	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		Low	
Potential impact (next 10 years)	High		Low	

The losses her refer to the entire world; in Europe losses over the last 10 years have been limited. According to EM-DAT (Delforge et al., 2025), in the past 10 years, 55 eruptions with direct losses have been registered. More than 1 100 people died and 3 183 564 000 $ of damage have been recorded. Is important to say that these figures are related to all the volcanoes that erupted worldwide, not considering only the cross bordering ones because this info is not available.

Furthermore, we can say that, after our analysis, there are not any volcanoes located in a cross bordering area that erupted in the recent 10 years.

Indirect effects include:

- Air traffic disruption;
- technical failures due to ash deposits;
- disruption to local services and damage to local economy;
- pollution (air, soil, water);
- weather and climatic anomalies

In terms of potential impacts (UNDAC, 2024, chapter K.5.3), pyroclastic flows kill all living forms on their path and cause destruction. Lava flows completely destroy anything on the path: buildings infrastructures crops and forests. Tephra fallout can cause damage to human. Volcanic gases and aerosols (air pollution) can impact large areas due to release of various gases, including sulphur dioxide, carbon dioxide, and hydrogen sulphide, into the atmosphere contributing to respiratory problems, acid

rain, and climate disruption. Potential impacts are health (respiratory issues), buildings, infrastructure, and agriculture, particularly if the accumulation is heavy.

Data collection:

- NCEI/WDS Global Significant Volcanic Eruptions Database (NGDC/WDS, 2025b);
- EM-DAT (Delforge et al., 2025);
- ERCC: ECHO Daily Flash[71],
- GDACS GDA

Level uncertainties: Low

Risk drivers and interactions

Earthquake

Risk drivers	• Urbanisation; • Technological developments; • Poverty and inequality; • Poorly planned urban development; • Weak governance; • Developments in information technology and digitalisation
Hazards triggering	• Volcano eruption
Hazards triggered by	• Fire • landslide, • tsunami, • Natech, • liquefaction, • pollution
Cascading impacts	• Physical damage leading to increased demand for materials and workers; • damage to buildings -> casualties, need to shelter inhabitants, loss of cultural heritage, business interruption; • Disruption of essential services (damage to infrastructure) • difficulties in emergency operations, • long-term disturbance of trade and other economic activities
Compound relationships	• fire (Coar et al., 2021); • extreme weather; • Aftershocks (Harati et al., 2024); • Epidemics (Silva et al., 2024);

71 ERCC portal, ECHO Daily Flash: *https://erccportal.jrc.ec.europa.eu/ECHO-Products/Echo-Flash#/echo-flash-items?pageIndex=1&pageSize=10&ht=V0&st=Published*

Tsunami

Risk drivers	• climate change (due to sea level rise) (Grezio et al., 2024; Goda et al., 2024); • urbanisation (higher level urbanisation degree of coastal areas); • environmental degradation (soil coverage); • poverty and inequality (lack of risk awareness information and training; humanitarian camps); • poorly planned urban development (urban planning rarely takes into account the tsunami hazardous areas); • weak governance (applies to all hazards); • demographical developments (higher exposure); • Developments in information technology and digitalisation (huge impact on the success of the EW4All, minimum technological infrastructure is not there to disseminate the warning to the population).
Hazards triggering	• Earthquakes; • coastal/underwater landslides; • volcanic eruptions; • meteoroid impacts;
Hazards triggered by	• Coastal inundation; Fire (industrial); • Marine pollution (chemical); • Negative wave.
Cascading impacts	• Structural collapse; • Disruption of essential services • Coastal erosion; • Power outage; • Water contamination; • Damage from debris; • Long term damage to environment, agriculture, and fisheries, due to salt water deposits.
Compound relationships	• Earthquake + Landslide + tsunami (Suppasri et al., 2021); • Volcanic eruption + landslide + tsunami (Karstens et al., 2023).

Volcanoes

Risk drivers	• urbanisation (volcanoes prone areas); • demographical developments;
Hazards triggering	• None
Hazards triggered by	• Tsunami; • Mudflows and landslides (lahar); • Avalanches; • Wildfires
Cascading impacts	• Air traffic disruption; • Disruption of essential services • technical failures due to ash deposits; • disruption to local services and damage to local economy; pollution (air, soil, water); • weather and climatic anomalies; health

Compound relationships	• earthquake;[72] • landslide;[73] • wildfire; • health

Gaps and needs

	Operational	Research	Policy
Earthquake	N/A	Lack of data on exposure to earthquake risks, which is necessary to understand the impacts and develop effective mitigation strategies (Gkatzogias et al, 2022b).	Need for effective planning and allocation of resources to implement recommended mitigation measures (Gkatzogias et al, 2022b).
Tsunami	Global, systematic loss data collection: Need for standardised data collection. Offshore sea level data collection: Need for more data to improve tsunami forecasting. End-to-end tsunami warning chain: Need for improvement to reach citizens in a timely manner. Community preparedness: Need for better preparedness, including emergency plans and knowledge of safe behaviours.	Lack of coastal bathymetry data: Need for more research on coastal bathymetry.	N/A
Volcanoes	Global monitoring scheme: Need for a comprehensive and coordinated monitoring system for volcanoes. Shared metrics and standards: Need for standardised metrics and standards to facilitate data sharing and comparison across different volcanic monitoring systems.	N/A	N/A

72 On 15 January 2022 at 4.15 UTC (17.15 local time), a huge eruption triggered tsunami waves that have been reported in several countries of the Pacific Ocean, particularly Tonga, Fiji, Samoa, Vanuatu, Solomon Islands, USA, Mexico, Peru and Chile. The eruption generated an ash plume 19.2 km high, and the ashfall reached Tonga (particularly Tongatapu Island) and the islands of Vatoa and Ono-i-Lau in Fiji. The combined events resulted in three fatalities, several injured people and hundreds of destroyed buildings particularly across Tonga island.

73 An example of this occurred in the Mount Marapi area (Sumatra province, Indonesia) on 11 May 2024 and was characterized by a lahar event (a cold mixture of water and volcanic deposits that flows down the slopes of a volcano typically in channelised valley) triggered by recent heavy rainfall. This phenomenon probably involved the recent ash deposits resulted by the eruption of 23 December 2023, these deposits have been saturated by the rain and flew down the slopes of the Marapi and resulted in more than 70 fatalities.

Policy reference and adaptation/mitigation measures

Earthquake

Adaptation measures in place	Climate change adaptation not relevant to earthquake risk.
Recommended adaptation measures	Climate change adaptation not relevant to earthquake risk.
Mitigation measures in place	National seismic risk analysis (Sousa & Tsionis, 2025), implementation of standards for the design of structures for earthquake resistance (Eurocodes[74]), awareness campaigns, drills, urban planning
Recommended mitigation measures	Renovation of elements at risk, increased insurance coverage
Policy references	Commission Recommendation of 8 February 2023 on Union disaster resilience goals (European Commission, 2023c)

Tsunami

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	Four Intergovernmental Coordination Groups (ICGs), corresponding to the regions Pacific (ICG/PTWS), Caribbean (ICG/CARIBE-EWS), Indian Ocean (ICG/IOTWMS), and Mediterranean, Northeast Atlantic and its Connected Seas (ICG/NEAMTWS), have been established to address regional needs in terms of tsunami warning systems and mitigation measures (including community preparedness programmes). Tsunami Service Providers of each ICGs officially provide timely tsunami information products to the designated Tsunami Warning Focal Points / National Tsunami Warning Centres (TWFP/NTWC) of Member States. It is then the responsibility of mandated national organisations operating within the

74 EUROCODES https://eurocodes.jrc.ec.europa.eu

	legal framework of the sovereign nation in which they reside and serve, to provide alerts to their citizens and communities. There are currently 12 accredited Tsunami Service Providers (TSPs) that monitor seismic and sea level activity and issue timely tsunami threat information within the IOC-UNESCO framework to NTWCs / TWFPs and other TSPs operating within an ocean basin. Coastal areas at risk of tsunamis are alerted through warnings that provide a lead-time of several minutes to hours, allowing people to evacuate to safety. However, It might not be possible to issue tsunami warnings with sufficient lead-time, especially for those coastal regions that are very close to the tsunami source zones. In such cases, citizen's knowledge of the natural signs of an upcoming tsunami is essential. Community preparedness programmes, implemented at full scale, thus including the fulfilment of all 12 indicators (IOC UNESCO, 2025b), which include -among other things- evacuation plans; coastal detection and alarm systems.
Recommended mitigation measures	The effective mitigation measures are corresponding to those listed as indicators of the IOC Tsunami Ready Programme (IOC UNESCO, 2025b). Not all coastal communities satisfy some/all of them. The mitigation measures at local level are implemented in a patchy manner in all basins at global level.
Policy references	Union Disaster Resilience Goals 2023/C 56/01; (European Commission, 2023c); Regulation (EU) 2021/836 of the European Parliament and of the Council of 20 May 2021 amending Decision No 1313/2013/EU on a Union Civil Protection Mechanism; (European Parliament and Council, 2021a); EW4All.

Volcanoes

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	evacuation plans; monitoring; land use planning; risk communication
Recommended mitigation measures	N/A
Policy references	EW4All; UCPM (European Parliament and Council, 2021a); Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015).

Biological

Biological threats cover four risks: Communicable diseases, particularly pathogens with high epidemic potential, Antimicrobial Resistance (AMR), Pollution-Driven Non-Communicable Diseases Adverse Health Effects (NCD) and Illicit Drug Abuse, Trafficking, and Risk to Public Health.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Pathogens with high epidemic potential	Yes	Yes	Yes	Yes
Antimicrobial Resistance (AMR)	Yes	Yes	Yes	Yes
Pollution-Driven Non-Communicable Diseases Adverse Health Effects	Yes	Yes	Yes	Yes
Illicit Drug Abuse, Trafficking, and Risk to Public Health	Yes	Yes	Yes	No

Epidemics transcend national boundaries. Infectious diseases are capable of spreading rapidly and globally, necessitating collaborative international efforts for effective containment and management. The emergence of novel pathogens and the adaptation of existing ones to human hosts constitute two distinct pathways through which epidemics present an evolving risk. Recent events, such as the COVID-19 pandemic, the outbreak of avian influenza H5N1 among poultry with spillover to humans, recurrent Filovirus outbreaks such as Ebola and Marburg in West and Central Africa, and the emergence of a new variant of mpox in Central Africa, exemplify the dynamic and shifting nature of epidemic risks. A One Health approach, recognizing the interconnectedness of human, animal, and environmental health, is essential to understanding and mitigating these risks, as many emerging pathogens originate from animal and environmental sources or are amplified by environmental factors. Climate change and escalating habitat loss will significantly contribute to the emergence of new pathogens and the adaptation of existing ones in the coming years and decades. Warmer temperatures, for example, have already allowed disease-carrying vectors to expand their distribution, increase further the spillover potential, highlighting the need for a holistic and integrated approach to epidemic risk management that considers the complex relationships between human, animal, and environmental health.

Climate factors can influence the spread of infectious diseases by affecting the establishment, abundance and behaviour of vectors (like mosquitoes and ticks), altering the distribution of wildlife reservoirs, and impacting human vulnerability and exposure. With climate change, bacterial infection rates may increase, and diseases can spread to higher altitudes and latitudes where they were not previously found. Increasingly higher temperatures are intimately linked to antimicrobial resistance (AMR), because they are associated with increased bacterial growth rates and horizontal gene transfer. Risk assessments increasingly incorporate climate models and projections to anticipate changes in disease patterns and to inform public health strategies for prevention and preparedness in the face of a changing climate. Epidemics can be classified as high-impact, low-probability risks due to their infrequent but potentially devastating effects on public health, the economy, societal order, and international stability. Although large-scale epidemics are rare, their ability to cause extensive morbidity and mortality, societal disruption, and profound economic damage—as demonstrated by the COVID-19 pandemic-is very high.

Finally, the changing geopolitical situation, a potential weaponisation of biological threats, and misinformation increase the risk of epidemics. **Antimicrobial Resistance (AMR)** is a complex, multi-faceted and cross-border issue, affecting human, animal and plant health, and the environment. It requires a strong and coordinated response within One Health approach as AMR transmission dynamics is between humans, animals, plants and the environment, hence it cannot be tackled efficiently by one sector independently or by individual countries alone (Council of the European Union, 2023). WHO has declared that AMR is one of the top 10 global public health threats facing humanity. European Commission classifies AMR as one of the top three priority health threats in the EU (European Commission, 2022a) and AMR threatens the effective prevention and treatment of an ever-increasing range of infections caused by such agents as bacteria, parasites, viruses, and fungi. It is estimated that bacterial AMR was directly responsible for 1.27 million global deaths in 2019 and contributed to 4.95 million deaths (Antimicrobial Resistance Collaborators, 2022). Evidence suggests that changes occurring

in the natural environment due to the climate crisis are increasing the spread of infectious disease, including drug-resistant infections. The frequency and severity of extreme weather events and natural disasters (such as hurricanes, typhoons, storms, heatwaves, floods and wildfires) are increasing because of the climate crisis and can damage infrastructure and consequently increase the spread of drug-resistant infections. For example, natural disasters as well as war conflicts can cause unhealthy living conditions and/or population displacement, which can increase the spread of drug resistant infections and disease and place increased pressure on health systems (Global Leaders Group on AMR, 2021). AMR, being defined as a "silent pandemic" can be classified as a high-impact, low-probability risk. Although the evolution of AMR epidemics globally is growing slowly, its implications, causing extensive morbidity and mortality, societal disruption especially in low-income and developing countries, and huge economic impact, is high.

Cross-Border Pollution and Health: Cross-border pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to pollutants can occur through various routes, including air, water, food, and soil. In this section, we will discuss the effects of cross-border pollution on human health, including the impact of air, water, food, and soil pollution.

Air Pollution: Air pollution is a major public health concern, with far-reaching consequences for human health. Exposure to air pollutants can occur through inhalation, and can cause a range of health effects, including:

- Respiratory problems: Air pollution can exacerbate respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD).
- Cardiovascular disease: Exposure to air pollutants has been linked to an increased risk of cardiovascular disease.
- Cancer: Air pollution has been linked to an increased risk of various types of cancer, including lung cancer and breast cancer.
- Neurological effects: Exposure to air pollutants has been linked to neurological effects, including headaches and cognitive impairment.

Water Pollution: Water pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to water pollutants can occur through ingestion, and can cause a range of health effects, including:

- Gastrointestinal problems: Water pollution can cause gastrointestinal problems, including diarrhea and vomiting.
- Skin problems: Exposure to water pollutants can cause skin problems, including rashes and itching.
- Cancer: Water pollution has been linked to an increased risk of various types of cancer, including bladder cancer and kidney cancer.
- Reproductive problems: Exposure to water pollutants has been linked to reproductive problems, including birth defects and infertility.

Food Pollution. Food pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to food pollutants can occur through ingestion, and can cause a range of health effects, including:

- Gastrointestinal problems: Food pollution can cause gastrointestinal problems, including diarrhea and vomiting.
- Cancer: Food pollution has been linked to an increased risk of various types of cancer, including colon cancer and breast cancer.
- Reproductive problems: Exposure to food pollutants has been linked to reproductive problems, including birth defects and infertility.
- Neurological effects: Food pollution can cause neurological effects, including headaches and cognitive impairment.

Soil Pollution: Soil pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to soil pollutants can occur through ingestion, and can cause a range of health effects, including:

- Gastrointestinal problems: Soil pollution can cause gastrointestinal problems, including diarrhea and vomiting.
- Cancer: Soil pollution has been linked to an increased risk of various types of cancer, including lung cancer and kidney cancer.
- Reproductive problems: Exposure to soil pollutants has been linked to reproductive problems, including birth defects and infertility.
- Neurological effects: Soil pollution can cause neurological effects, including headaches and cognitive impairment.

Transboundary Pollution: Transboundary pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to transboundary pollutants can occur through various routes, including air, water, food, and soil. Transboundary pollution can cause a range of health effects, including:

- Respiratory problems: Transboundary pollution can exacerbate respiratory conditions such as asthma and COPD.
- Cardiovascular disease: Exposure to transboundary pollutants has been linked to an increased risk of cardiovascular disease.
- Cancer: Transboundary pollution has been linked to an increased risk of various types of cancer, including lung cancer and breast cancer.
- Neurological effects: Exposure to transboundary pollutants has been linked to neurological effects, including headaches and cognitive impairment.

International cooperation is essential for addressing cross-border pollution and its effects on human health. Governments, international organizations, and civil society groups must work together to develop and implement policies and regulations that prevent and mitigate the effects of cross-border pollution. Cross-border pollution is a significant public health concern, with far-reaching consequences for human health. Exposure to pollutants can occur through various routes, including air, water, food, and soil. The effects of cross-border pollution on human health are complex and multifaceted, and require a comprehensive approach to prevention and mitigation. International cooperation is essential for addressing cross-border pollution and its effects on human health.

Pollution-driven NCDs are increasingly recognized as a critical global health challenge. The Lancet Commission reports that pollution is responsible for approximately 9 million deaths annually. Modern pollutants such as ambient air pollution and toxic chemicals (e.g., lead) are rising, primarily due to industrialization and urbanization. Addressing these emerging risks requires comprehensive policy measures and international cooperation. “The Global Burden of Disease Study 2019 (GBD 2019 Diseases and Injuries Collaborators, 2020) highlights the substantial impact of pollution on non-communicable diseases, emphasizing the urgent need for action.”

Climate change exacerbates pollution-related health risks, with extreme weather events and temperature fluctuations affecting air quality and pollutant dispersion. Integrating climate scenarios into pollution risk assessments is crucial for developing adaptive strategies and mitigating health impacts. The intersection of climate change and pollution necessitates coordinated efforts to address both challenges, promoting sustainable development and resilience. While pollution-driven NCDs are a high-impact issue, they are often under-recognized in policy discussions. The cumulative effects of pollution on health and the environment represent a significant risk, with potential long-term impacts on public health and sustainability.

Illicit drugs are often produced in one country, trafficked through others, and consumed in another, making them a transnational issue. Weak border controls, corruption, and lack of effective law enforcement in some countries can facilitate the spread of illicit drugs across borders. Cross-border

migration and global inequalities can exacerbate the vulnerability of certain populations to drug use and trafficking. The emergence of new drugs, the difficulty to track drug trafficking, or the spread of trafficking of abuse drugs present a real risk to society. This can have impacts on public health, economics, social stability, and on the facilitation of transnational organized crime.

Direct effects of climate change (CC): CC can directly impact the production of illicit drugs. For example, changing weather patterns may affect the cultivation of crops like coca and opium poppies, potentially leading to shifts in production areas and increased competition for resources. Indirect effects: extreme weather events (due to CC), like floods or wildfires, can increase social and economic instability. This, in turn, can increase the vulnerability of certain people to drug abuse. As well as water shortages, food insecurity, and forced migration, all consequences of CC, can impact the vulnerability to drug abuse.

Illicit drug abuse and trafficking is a high impact (significant economic, societal, national security impacts), but probable situation (since it is widespread, persistent, and difficult to eradicate), so not deemed to be a high impact, low probability risk.

Loss, damages, and potential impacts

Pathogens with high epidemic potential	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	High	High
Potential impact (next 10 years)	High	High	High	High

Past epidemics disrupted the workforce, halted production, impeded trade, and reduced consumer spending, leading to substantial direct economic **losses and damages** and a downturn in economic activity. Some sectors, such as tourism, transportation, entertainment, and events, are particularly vulnerable. The global economic loss due to the COVID-19 pandemic has been immense, with a loss in EU's GDP by about 6% in 2020, a substantially larger decline than the one faced by the EU in 2009 during the global financial and economic crises. In addition, zoonotic diseases can have repercussions on economy due to both direct medicals costs on humans and animal health cost, as well as the loss of productivity, the impact on agriculture, food safety, and trade. Epidemics resulted in the loss of countless lives, with over 1 million confirmed COVID-19 deaths in the EU alone (Eurostat, 2025). Epidemics can have long-lasting effects on public health, including persistent physical damage like Long Covid. They also disrupted healthcare services, reducing access to care for non-epidemic-related health issues and affecting various aspects of life, health, and community dynamics. Zoonotic and vector-borne diseases can also impact on the environment, due to the disruption of ecosystems, the contamination of water and soil, or due to the increased use of pesticides and other chemicals to control disease vectors.
The indirect economic losses and damages caused by epidemics (focusing on COVID-19) are numerous and often challenging to quantify. For instance, long-term health effects resulted in higher healthcare costs and diminished the workforce. Additionally, tourism suffered strongly due to travel restrictions, while uncertainty during epidemics deterred investments, ultimately impacting economic growth and development. Some sectors, such as tourism, transportation, entertainment, and events, are particularly vulnerable. Pathogens and diseases management require significant investments in therapies and vaccine development, production, and distribution, as well as in monitoring and surveillance. People, animals, and goods may need to be isolated. Infected animals may need to be euthanized or culled, leading to economic losses and market disruptions. Epidemics have impacted mental health, education, and social dynamics. Particularly, COVID-19 has heightened mistrust in institutions, including research organizations and policymakers, resulting in wide-ranging, complex, and enduring consequences.

The **potential impact** and escalating epidemic risk is underscored by the resurgence of mpox in Central Africa and the spread of avian influenza H5N1 across the Americas, particularly due to the concerning adaptability of the virus to infect mammals and humans. Even more alarming is the possibility of human-to-human transmission, which significantly heightens the threat posed by these emerging infectious diseases. The spread of mosquito-borne diseases is also on the rise, driven by climate change. These factors contribute to a more conducive environment for disease transmission, amplifying the risks and potential losses associated with epidemics. While a large-scale outbreak akin to COVID-19 may be unlikely in the immediate future, the potential for smaller outbreaks is significant, and their cumulative direct and non-direct economic and non-economic impacts could be substantial. The dual threat of the climate crisis and antimicrobial resistance will have the most devastating impacts on low-and middle-income countries and small island developing states. As we move forward, it is reasonable to anticipate that another pandemic will emerge, resulting in profound economic losses, societal and emotional tolls, disruption of healthcare systems, and a lasting impact on community well-being.

Data collection:

- The European Surveillance System (TESSy).
- Provided by ECDC in order to collect, analyse and disseminate surveillance data on infectious diseases in Europe;
- EpiPulse: integrates several surveillance systems that were previously independent (The European Surveillance System (TESSy), the five Epidemic Intelligence; Information System (EPIS) platforms and the Threat Tracking Tool (TTT), launched in 2021;
- EIOS: global system for public health intelligence developed under the leadership of WHO, and adopted by a number of public health institutions and network worldwide, including HERA, ECDC, EFSA, the Global Health Security Initiative and a number of EU member states. It covers all hazards that can affect public health from a One Health perspective. It aggregates a wide range of selected publicly-available sources, including ProMED and WHO DON, and media;
- ProMED: largest publicly-available system conducting global reporting of infectious disease outbreaks;
- WHO DON: provides information on confirmed acute public health events or potential events of concern;
- ATHINA: future DG HERA's platform for intelligence gathering and threat assessment, to handle preparedness to public health threats and monitor medical-counter measures supply chains;
- EWRS: DG SANTE's Early Warning and Response System to monitor and respond to cross-border public health threats.

Level uncertainties: High

There is high uncertainty in predicting the potential risks of epidemics due to several complex and interconnected factors:

1. Unpredictable Emergence: New pathogens can emerge suddenly and unexpectedly due to genetic mutations, zoonotic spillovers, and other ecological changes, making it challenging to anticipate when and where an outbreak will occur.
2. Complex Transmission Dynamics: The ways in which diseases spread among populations involve intricate interactions between hosts, vectors, and environmental conditions, which can be difficult to model accurately.
3. Global Mobility: The extensive and rapid movement of people and goods around the world can quickly turn a localized outbreak into a global epidemic, complicating predictions about the spread and impact of a disease.
4. Human Behavior: Variability in human behavior, such as the level of adherence to public health measures, can significantly influence the course of an epidemic and is hard to predict or quantify.

5. Socioeconomic Factors: Diverse socioeconomic conditions across regions can affect the vulnerability of populations to epidemics and the resources available for response, adding layers of uncertainty to risk assessments.
6. Potential lack of early detection/notification: epidemics can start spreading, even across countries, before they are detected by surveillance systems and officially notified.

Due to these and other factors, predicting the timing, location, severity, and progression of epidemics involves significant uncertainty.

Antimicrobial Resistance (AMR)	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High/Low[75]	High	High/Low	High
Potential impact (next 10 years)	High	High	High	High

World Bank economic simulation tools quantified the losses that AMR may inflict on the global economy between 2017 and 2050 (World Bank, 2017). Simulations included two scenarios, corresponding to low AMR impacts and high AMR impacts. AMR impacts were modelled as shocks to labour supply and livestock productivity—a conservative approach that underestimates AMR's full economic effects.

The analysis of the global burden of bacterial AMR for 1990-2021 estimated that, 4.71 million deaths were associated with bacterial AMR including 1.14 million deaths attributable to bacterial AMR (Antimicrobial Resistance Collaborators, 2022).

The AMR related indirect economic losses can negatively impact national economies, which may have fewer and less productive workers and populations spending more on health care. If infections cannot be prevented and treated, trade and agriculture can also be negatively affected, with increased death and illness among farmed animals. This would lead to lower productivity, lower supply of livestock products (both domestically and for ex-ports) and increased prices of major sources of food protein.

The analysis of the global burden of bacterial AMR for 1990-2021 estimated that, 1.91 million deaths at-tributable to AMR and 8.22 deaths associated with AMR could occur globally by 2050 (2)[S(16]. The analysis also showed that increased financial pressure on health systems could happen due to more hospitalizations, longer stays, expensive diagnosis and treatment, and reduced ability to provide safe treatments.[S(17] Extra health care expenditures would rise to $0.22 trillion annually in the low-AMR. This figure represents thirty times the amount that is likely to be needed in annual investments to contain AMR worldwide (World Bank, 2017).

The future economic impact of AMR under five different scenarios on four areas of the economy (health system costs, the labour market, tourism and domestic hospitality) was modelled (WOAH and World Bank, 2024). This is the broadest range of economic shocks ever modelled for AMR. In a scenario where countries fail to contain drug resistance, a staggering US$ 1.7 trillion annual reduction in global economic output by 2050 could be faced, amounting to a 0.88% decrease in GDP. This would not only escalate hospital treatment costs, but also adversely affect tourism and domestic hospitality.

75 High/low depends on the given scenario

Data collection:

- European Centre for Disease Prevention and Control (ECDC): The ECDC collects and analyses data on antimicrobial resistance (AMR) and healthcare-associated infections (HAIs) through the European Surveillance System (TESSy)[76]:
- European Antimicrobial Resistance Surveillance Network (EARS-Net): The European Antimicrobial Resistance Surveillance Network (EARS-Net) is the largest publicly funded system for antimicrobial resistance (AMR) surveillance in Europe. Data from EARS-Net play an important role in raising awareness at the political level, among public health officials, in the scientific community, and among the general public. Public access to descriptive data (maps, graphs and tables) are available through the ECDC Surveillance Atlas of Infectious Diseases[77]; more detailed analyses are presented in annual reports and scientific publications.
- European Surveillance of Antimicrobial Consumption (ESAC): ESAC-Net (formerly ESAC) is a Europe-wide network of national surveillance systems, providing European reference data on antimicrobial consumption. ESAC-Net collects and analyses data on antimicrobial consumption from EU and EEA countries, both in the community and in the hospital sector.WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS): The WHO collects and analyses data on AMR through the Global Antimicrobial Resistance Surveillance System (GLASS), which provides a standardized framework for countries to collect and share data on AMR[78]
- Global Antibiotic Research and Development Partnership (GARDP): GARDP collects and analyses data on AMR and antibiotic use, providing insights into the global burden of AMR and the need for new antibiotics[79]
- Global Database for Tracking Antimicrobial Resistance (AMR) Country Self- Assessment Survey (TrACSS): Aims to monitor country progress in the implementation of the national actions plans, via annual AMR country self-assessment surveys (TrACSS) which are jointly administered by FAO, WOAH, WHO and UNEP[80]
- Global Point Prevalence Survey (Global-PPS): A worldwide survey of antibiotic use and resistance in hospitals, providing data on antibiotic use and resistance patterns[81]
- International Collaboration on Antimicrobial Resistance (ICAR): A global initiative to improve AMR surveillance and research, providing data on AMR trends and patterns in Low- and Middle-income countries (LMICs)[82]

Level uncertainties: Medium/High

Estimating the global burden of AMR, including the number of deaths and economic costs, due to limited data and variability in reporting as well as limited data on AMR prevalence, antibiotic use/misue/overuse, and resistance patterns in humans, animals and the environment, especially in low- and middle-income countries represents a high level of uncertainty. Understanding the impact of climate change, agriculture, and environmental factors on AMR, as well as the effectiveness of interventions to mitigate these factors represents a medium level of uncertainty. Moreover, there is incomplete understanding of the complex mechanisms driving AMR, including the role of genetic mu-tations, horizontal gene transfer, and environmental factors. Uncertainties are also associated with: the transmission of AMR bacteria between humans, animals and the environment; the economic and social drivers of AMR, including poverty, lack of access to healthcare, and cultural practices; the ef-fectiveness of

76 https://www.ecdc.europa.eu/en/antimicrobial-resistance/surveillance-and-disease-data
77 https://atlas.ecdc.europa.eu/public/index.aspx?Dataset=27&HealthTopic=4
78 https://www.who.int/initiatives/glass
79 https://gardp.org/
80 https://amrcountryprogress.org/#/map-view
81 https://www.global-pps.com/project/
82 https://icars-global.org

stewardship programs.

Pollution-Driven Non-Communicable Diseases Adverse Health Effects	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	High	High
Potential impact (next 10 years)	High	High	High	High

Pollution-related health issues lead to significant economic **losses and damages**, including healthcare costs and productivity losses. The World Bank estimates that pollution costs the global economy billions annually, with impacts on labour supply and healthcare systems. Reducing pollution can mitigate economic losses and improve public health outcomes. Economic impacts are particularly severe in low- and middle-income countries, where pollution control measures are often underfunded.

Beyond direct economic impacts, pollution contributes to social and health inequalities. It exacerbates health disparities, particularly affecting vulnerable populations such as children, the elderly, and those with pre-existing conditions. These non-economic impacts underscore the need for inclusive and equitable pollution control strategies.

Pollution affects mental health and social well-being, contributing to stress and reduced quality of life. These non-economic impacts highlight the need for comprehensive public health strategies that address both the physical and mental health effects of pollution. Pollution impacts agriculture and food security, affecting crop yields and livestock health. This leads to increased food prices and economic instability, particularly in regions heavily dependent on agriculture. Sustainable agricultural practices and pollution control measures are essential to ensure food security and economic resilience.
Investment in pollution control technologies and infrastructure can create economic opportunities and drive innovation. However, the initial costs of implementing these measures can be substantial, requiring strategic investment and international cooperation.

Pollution-driven NCDs pose a significant public health challenge when it comes to **potential impacts**, affecting population health and well-being. Addressing these issues requires comprehensive health policies, public awareness, and community engagement to promote healthy environments and lifestyles.

Data collection:

1. Global Burden of Disease (GBD) Study: A comprehensive source that assesses the burden of diseases related to pollution, such as respiratory and cardiovascular diseases, by providing data on mortality and morbidity. It offers insights into the global impact of pollution on health, quantifying the contribution of air and chemical pollutants to diseases like asthma and heart disease.
2. European Environment Agency (EEA): Offers data on air and noise pollution in Europe, linking environmental quality to public health outcomes, particularly NCDs. It analyses the effects of environmental pollution on public health, reporting on how air and noise pollution contribute to conditions like hypertension and mental health disorders.
3. WHO Global Health Observatory (GHO): Provides indicators on air quality and chemical safety, enabling analysis of the impact of environmental factors on public health. It tracks environmental health indicators that reveal the influence of air quality and toxins on public health, particularly chronic diseases.
4. Air Quality Index (AQI) Monitoring Systems: Delivers real-time data on air pollution levels, crucial for assessing exposure risks and their effects on respiratory and cardiovascular health. It provides critical data for evaluating the health risks of air pollution, helping to identify populations at risk for pollution-induced health conditions.
5. Earth Observing System Data and Information System (EOSDIS): Supplies satellite data to track environmental changes, helping to correlate pollution levels with public health impacts. It utilizes satellite data to monitor environmental pollutants and their health implications, aiding in the study of pollution-related disease patterns.
6. UNEP Live: A platform for accessing environmental data that can be used to study the relationship between pollution and health outcomes, such as NCDs. It facilitates access to data that connects environmental degradation with health outcomes, supporting research on pollution's role in NCDs.
7. Environmental Performance Index (EPI): Provides a framework for assessing countries' environmental health, including air quality, which is directly linked to NCD prevalence. It measures how well countries manage their environmental health, with a focus on air quality and its impact on public health metrics.
8. Global Environmental Monitoring System for Air (GEMS/Air): Focuses on air quality data that supports research on the adverse health effects of air pollution. It collects air quality data to study its effects on health, providing evidence for policies aimed at reducing pollution-related health burdens.

These databases and systems are crucial for understanding the link between environmental pollution and public health, particularly in the context of NCDs. They provide the data needed to inform research, policy-making, and public health initiatives.

Level uncertainties: High

1. Limited data on pollution exposure and health impacts in low- and middle-income countries
2. Uncertainties in predicting long-term health outcomes and climate interactions
3. Variability in policy implementation and effectiveness across regions
4. Limited understanding of the relationship between air and water pollution and NCDs
5. Uncertainties in predicting the health impacts of pollution on vulnerable populations
6. Complexity of the interactions between pollution, climate change, and NCDs""

Addressing these uncertainties requires robust data collection, research, and international cooperation.

There is high uncertainty in predicting the potential risks of pollution-driven NCD adverse health effects due to several complex and interconnected factors:

1. Unpredictable pollution exposure: Air and water pollution levels can fluctuate suddenly and unexpectedly due to various factors, making it challenging to anticipate when and where pollution-driven NCDs will occur.
2. Complex interactions between pollution and NCDs: The ways in which pollution affects NCDs involve intricate interactions between pollutants, human health, and environmental conditions, which can be difficult to model accurately.
3. Global climate change: Climate change can exacerbate pollution-driven NCDs by altering air and water pollution levels, as well as the distribution of pollutants, making it harder to predict the spread and impact of NCDs.
4. Limited understanding of the health impacts of pollution on vulnerable populations: Diverse socioeconomic conditions across regions can affect the vulnerability of populations to pollution-driven NCDs and the resources available for response, adding layers of uncertainty to risk assessments.
5. Variability in policy implementation and effectiveness across regions: Differences in policy implementation and effectiveness across regions can affect the effectiveness of measures to reduce pollution and mitigate the health impacts of NCDs.
6. Potential lack of early detection/notification: Pollution-driven NCDs can start spreading, even

across countries, before they are detected by surveillance systems and officially notified.

Due to these and other factors, predicting the timing, location, severity, and progression of pollution-driven NCD adverse health effects involves significant uncertainty.

Illicit Drug Abuse, Trafficking, and Risk to Public Health	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	High	High
Potential impact (next 10 years)	High	High	High	High

In terms of **losses and damages**, the lucrative nature of the illicit drug trade can lead to economic instability, corruption, and violence in any of the countries involved in the supply chain. The drugs market is the largest criminal market in Europe, with a minimum year retail value of €30 billion. In addition, a big economic impact is due to the cost of healthcare related to illicit drugs. There may be an underestimation of overdose-related deaths, as some cases may not have been captured by monitoring systems. According to the European Union's drug agency, the estimated overdose mortality rate in the European Union in 2022 was 22.5 deaths per million population aged 15 to 64.

The cross-border trade of illicit drugs can spread drugs-related health problems, such as addiction, overdoses, and drug-resistant diseases, across countries and regions. The mortality rate due to overdoses in the European Union in 2022 was estimated at 22.5 deaths per million population aged 15 to 64. As of 2020, over 525,000 individuals in Europe were enrolled in opioid substitution treatment programs, primarily for heroin addiction. Global inequities can render certain populations even more vulnerable. Drug use and abuse can also spread drug-related transmission of infectious diseases, such as HIV and hepatitis. In 2022, over 40 % of new HIV diagnoses linked to injecting drug use in the European Union. Drug can also exacerbate existing mental health conditions and increase the risk of developing new ones.

Drug use can lead to losses in terms of economic productivity. It can increase absenteeism and cognitive impairment, impacting on job performance and economic output. The increase of crimes related to illicit drugs also lead to an increase of justice system costs. Substantial costs are associated with law enforcement such as enforcement, investigations, and training. Research cost: studying drug use, developing new treatments, and evaluating policies. Drug trafficking and use has an impact on communities, and society, fuelling crime placing a heavy economic and social burden on the entire community.

Drugs abuse has several social impacts, such as family breakdown, social isolation, and increased violence and crimes (including drugs and arms trafficking, corruption, and human exploitation for trafficking). In addition, drug trafficking can have national security implications, such as the potential for unauthorized organizations to profit from the drug trade. Another indirect effect is on the environment, since drugs can contaminate water (rivers, lakes, and groundwater) through chemicals used for drug production or through improper disposal of drug residues. This, in turn, can harm aquatic life, disrupt ecosystems, and pose risks to human health. Another indirect effect is the deforestation and consequent habitat loss, since the cultivation of several drugs involves the previous deforestation to clear land.

The direct **potential impacts** of Illicit Drug Abuse, Trafficking, and Risk to Public Health include:

1. Increased instability in the countries involved, impacting economic development and security;
2. Emergence of new synthetic drugs, creating new markets and associated economic challenges;
3. Increased costs due to hospitalizations for treating drugs-related diseases;

4. Growing number of new illegal psychoactive substances;
5. Increased drug overdose deaths (e.g., fentanyl)
6. Increasing spread of existing infectious diseases (e.g., HIV/AIDS, hepatitis C) or emergence of new infectious disease
7. Exacerbation of mental health problems (e.g., higher rates of addiction, depression, anxiety, and psychosis)

Furthermore, indirect potential impacts are significant and include:

1. Significant burden on healthcare systems due to Increased drug-related illnesses and overdoses (even more significant impact on countries already affected by other conditions; e.g., poverty, social inequities, war);
2. Decreased economic productivity due to reduced workforce participation, absenteeism, and impaired cognitive function, caused by drug abuse;
3. Increase of drug-related crime (e.g., property crimes, violence, and drug trafficking) can disrupt economic activity and increase security costs
4. Disruption of family and social relationships, leading to social disorder, increased violence, and a decline in community quality of life;
5. Increase of violence and crimes has impacts on the security of countries;
6. Increase of drug-related chemicals pollution in wastewater and rivers due to drugs incorrect disposal and consequent mental and physical health problems to animals and humans;
7. Increase of deforestation and consequent habitat and biodiversity loss.

Data collection:

1. Every year, SCORE[83] coordinates a global wastewater monitoring effort, collecting samples from numerous cities and analysing them for a range of illicit substances over the course of a week.
2. The UNODC Drugs Monitoring Platform (drug use and treatment[84]; drug trafficking & cultivation[85]) is a powerful data platform that provides near real-time insights into drug trafficking trends, using interactive visualizations to help law enforcement, analysts, and policymakers stay ahead of emerging threats and make informed decisions to combat the drug trade.
3. The EMCDDA's data catalogue[86] is intended to make it easier for users to locate and access the agency's published data. Currently, the catalogue contains a subset of the agency's total data output, but it is being regularly updated and expanded as part of our commitment to open data principles. The catalogue's main function is to provide a discovery platform.

Level uncertainties: Medium/high

The level of uncertainties surrounding the cross-border drug trafficking and abuse issue is moderate to high due to limited data availability, the evolving nature of the problem, complexity of the issue, variability in enforcement and policy, and uncertainty in estimating the size of the illicit drug market.

83 https://score-network.eu/monitoring

84 https://dataunodc.un.org/dp-drug-use-prevalence

85 https://dataunodc.un.org/dp-drug-seizures

86 https://www.euda.europa.eu/data/data-catalogue_en

Risk drivers and interactions

Pathogens with high epidemic potential

Risk drivers	The 5 most common risk drivers are: • Globalization and increased movement: Global travel, trade, and movement increases the risk of pathogens to spread more rapidly and widely across the orld to new and susceptible populations. • Agricultural practices and farming: Intensive farming intensifies disease outbreaks among livestock, exerting evolutionary pressure that can lead to the emergence of new pathogens, including AMR ones, raising the risk of transmission to farm workers and potentially introducing novel infectious agents to human populations. • Environmental changes: Factors like climate change and habitat loss, driven by deforestation and urbanization, alter ecosystems and create conditions favourable for disease transmission. Specifically, climate change impacts environmental and ecological dynamics, altering pathogen ecology, species distribution, and the human-animal-environment interface, leading to the emergence of new disease hotspots, changing disease seasonality, and expanding the range of disease vectors, thereby increasing the potential for outbreaks and the re-emergence of diseases in human populations. Moreover, habitat loss disrupts ecosystems and increases human-wildlife interactions, creating conditions that elevate the risk of epidemics by facilitating zoonotic spillovers (where pathogens jump from animals to humans). • Mis/disinformation: The spreading of false information reduces the capacity to respond in a timely manner to epidemic outbreaks, can undermine public health measures, and lead to mistrust of the public. • Conflict and instability: Conflict scenarios hinder the timely identification, reaction to, and control of infectious diseases, as seen in the delayed handling of the monkeypox outbreak in the Democratic Republic of Congo (DRC) and the emergence of polio cases in Gaza.
Hazards triggering	• Pathogen emergence and adaptation: The appearance of new or mutated pathogens that can cause widespread illness. • Zoonotic Spillover: Increased interactions between humans and wildlife that heighten the risk of diseases jumping from animals to humans. • Public health infrastructure: Weak healthcare systems and inadequate public health measures that fail to detect and respond to outbreaks effectively.
Hazards triggered by	• Social instability: Heightened anxiety, fear, and stigmatization, which can lead to social unrest and breakdowns in community cohesion. • Supply chain interruptions: Disruptions in the production and distribution of essential goods, including food and medical supplies, resulting in shortages. • Healthcare systems strain: A sudden surge in healthcare demand can overwhelm hospitals and healthcare providers and lead to shortages of medical supplies, equipment, and personnel. This could put citizens at risk of not receiving appropriate treatments.

Cascading impacts	• Public health crisis: Overwhelmed healthcare systems and a strain on medical facilities and personnel, leading to reduced care quality and increased mortality rates, also for diseases not related to the epidemic (e.g. cancer screenings are delayed) • Disruption of essential services • *Economic disruption*: Significant economic downturn and recession due to business disruptions, loss of income, and increased healthcare costs. • Increased mental health issues: Rise in anxiety, depression, and other mental health disorders among affected populations. • Disruption of education: School closures and interrupted learning, impacting the future of children and young adults. • Social inequities: Worsening disparities in health and economic outcomes, disproportionately affecting marginalized communities. • Increased mortality: Surge in severe illness and number of deaths, especially impacting vulnerable groups such as the elderly and those with pre-existing health conditions.
Compound relationships	The most common hazards that have occurred, or have the potential to occur, simultaneously with an epidemic leading to a compound disaster event are: • Epidemics and social conflict: When an epidemic occurs simultaneously with a social conflict, the crisis intensifies as conflict exacerbates the conditions for disease spread. Conflicts disrupts healthcare systems, creates overcrowded living situations, and lead to resource scarcity, making populations more vulnerable to infection (e.g. emergence of polio cases in Gaza[87], or increased number of antimicrobial resistance in Ukraine[88]). • Epidemics and climate-related disasters[89],[90]: An epidemic occurring simultaneously with a climate-related disaster (like a flood) can lead to increased disease spread due to compromised sanitation and healthcare access. The growing severity of the climate crisis, marked by more frequent and intense extreme weather events, drive up the use of antimicrobial drugs across human, animal, and plant sectors, thereby accelerating the development of AMR. Climate-related changes can create an environment that fosters the growth of disease vectors like mosquitoes. • Epidemics and mis/disinformation[91]: Mis/disinformation often exacerbate public health crises. During an outbreak, the spread of false information can lead to confusion about transmission methods, prevention measures, and treatment options, undermining trust in health authorities. This misinformation can result in harmful behaviours, such as ignoring guidelines or using unproven remedies, which can worsen the epidemic's impact (Kotseva et al., 2023). • Concurrent epidemics: The simultaneous occurrence of multiple epidemics (e.g., COVID-19 and dengue fever outbreaks in Pakistan[92]) in the same region can overwhelm healthcare systems and complicate public health

87 Emergence of polio cases in Gaza: WHO, Humanitarian pauses vital for critical polio vaccination campaign in the Gaza Strip, 16.08.2024 (WHO, 2024)

88 War-torn Ukraine has become a breeding ground for lethal drug-resistant bacteria, 27.11.2024 (Cohen, 2024)

89 Overall climate change can exacerbate 58% of the infectious diseases, Mora et al., Nature Climate Change, Over half of known human pathogenic diseases can be aggravated by climate change (Mora et al., 2022).

90 Hurricane Katrina in New Orleans in 2005 led to increased West Nile Neuroinvasive diseases, Caillouet et al., Emerging Infectious Diseases, Increase in West Nile Neuroinvasive Diseases after Hurricane Katrina (Caillouet et al., 2008).

91 Misinformation during COVID-19 has perpetuated beliefs that led to vaccine avoidance, mask refusal, leading to increased morbidity (Caceres et al., 2022).

92 COVID-19 and Dengue in Pakistan - challenges: mutual symptoms leading to misdiagnosis, overburdened healthcare system, and a lack of proper vaccination (Khatri et al., 2022).

	responses, resulting in greater impacts than either epidemic would cause alone.

Antimicrobial Resistance (AMR)

Risk drivers	• Globalisation: The increasing mobility of people, animals and goods across borders facilitates the spread of AMR pathogens globally; • Human population growth and urbanization: The increasing human population and urbanization can lead to increased antibiotic use, poor sanitation, and inadequate infection control, driving the development of AMR • Socioeconomic factors: Poverty, lack of access to healthcare, cultural practices, inadequate access to clean water, sanitation and hygiene (WASH) for both humans and animals, particularly in low- and middle-income countries, increases the risk of AMR pathogen transmission; • Poor infection control practices: Inadequate infection prevention and control practices in health-care facilities and farms; • Agricultural practices: The use of antibiotics in animal agriculture for growth promotion and disease prevention, contributes to the development of AMR; • Contaminated environment: The presence of AMR bacteria in the environment, including in water, soil, and air, can lead to human exposure and infection;
	• Lack of new antibiotic development: The declining development of new antibiotics, combined with the excessive and inappropriate use of existing antibiotics in human medicine, animal agriculture and other settings, accelerates the development of AMR
Hazards triggering	• Human related hazards: antimicrobial overuse and misuse in medicine, antibiotics containing cosmetics and biocides utilization, and inadequate sanitation and hygiene in public settings. • Animal related hazards: Prophylactic and therapeutic antimicrobial misuse and overuse, using antimicrobials as feed additives, microbes resistant to antibiotics and resistance genes in animal excreta, and antimicrobial residue found in animal-origin food and excreta. • Food and environmental related hazards: Presence of antibiotic residues in food, naturally existing resistance genes, improper disposal of unused antimicrobials, contamination from waste in public settings, animal farms, and pharmaceutical industries, and the use of agricultural and sanitation chemicals. • Public health infrastructure: Poor sanitation, inadequate infection control measures and health managemen, particulalry in low- and middle-income countries • Climate change: It can alter the AMR-related pathogens' prevalence,transmission and evolution. • Poor waste management: Inadequate waste management, including the disposal of antibiotic containing waste. • Cross-border conflict crises and trade: conflict crises (wars) causing population displacement and damage of public health infrastructures and trade facilitate the rapid spread of AMR across borders and challenges effective control measures.

Hazards triggered by	• Public health hazards increase morbidity and mortality; increased risk of infections, particularly in vulnerable populations; reduced effectiveness of medical operations, such as organ transplants and cancer chemotherapy; limited ability to treat infections, particularly in low- and middle-income countries due tolack of effective antibiotics. • Food safety and environmental risks: AMR can increase the risk of foodborne illnesses and can have environmental implications, including the contamination of water and soil with antibiotic-resistant bacteria. • Increased risk of pandemics: as antibiotic-resistant bacteria can spread quickly and easily across borders. • Financial burden: Negative impact of global economies and GDP economy in various economic areas: Reduced economic growth, increased health-care costs, loss of productivity in the labour market, impacts on tourism and domestic hospitality • Social and psychological impacts: AMR can have social and psychological impacts, including increased anxiety, stress, and stigma, particularly for individuals and families affected by antibiotic-resistant infections.
Cascading impacts	• Human health impacts: increased morbidity and mortality, prolonged hospital stays, increased risk of infections, especially in vulnerable groups. • Healthcare system overload: Strain on medical facilities and personnel, leading to reduced care quality and increased mortality rates; • Animal and Plant health impacts: reduced effectiveness of animal health treatments and plant health treatments (leading to reduced crops yields and increased risk of plants diseases); • Food security impacts: increased risk of foodborne diseases, reduced food availability and access. • Environmental impacts: Risk of contamination of water sources and soils; reduced water quality and soil fertility; increased risks of waterborne and soil borne illnesses; risk of development of antibiotic-resistant bacteria in the environment. • Biodiversity impacts: AMR can reduce biodiversity, lead to the loss of ecosystem services and increase the risk of ecosystem disruption. • Economic impacts: Significant economic shocks to labour supply, loss of productivity, increased health-care costs and reduced livestock productivity; • Social impacts: Amplified disparities in health treatment especially in low-income and developing countries; increased anxiety, stress and stigma for persons and their families affected by AMR infections.

Compound relationships	• AMR and climate change: The convergence of antibiotic contamination, antimicrobial resistance (AMR), and climate dynamics (warmer tempertaures and changing precipitation patterns) poses a critical environmental and public health challenge. • AMR, global trade and travel: AMR is linked to global trade and travel, as the movement of people, animals, and goods can increase the spread of infectious diseases and the development of antibiotic-resistant bacteria. • AMR, human migration and war conflicts: Spread of infectious diseases and development of AMR bacteria can increase due to people movements cross borders and the disruption of healthcare systems. • AMR, animal health and food security: the overuse of antibiotics in animal agriculture can lead to the development of antibiotic-resistant bacteria in animals and cross-contamination of animal feed, which can then be transmitted to humans. • AMR, environmental pollution and degradation: AMR is related to water and soil pollution as the release of antibiotics into waterways and their use in agriculture can contribute to the development of and contamination by antibiotic-resistant bacteria and ultimately to the degradation of ecosystems. • AMR, poverty and economic inequality: AMR is related to economic inequality, as the lack of access to healthcare and antibiotics in low-income countries can increase the spread of infectious diseases and the development of antibiotic-resistant bacteria. • AMR, human behaviour and culture: AMR is linked to human behaviour and culture, as the misuse and overuse of antibiotics can be influenced by cultural and behavioural factors, such as the lack of awareness about antibiotic resistance and the pressure to use antibiotics in agriculture and human medicine. • The intersection of human, animal, and environmental health highlights the need for a One Health approach to addressing AMR, which recognizes the interconnectedness of these systems. Addressing AMR requires a comprehensive and multi-disciplinary approach that takes into account these intersecting issues and involves collaboration across sectors, including: human health, animal health, food security, environment and global governance.

Pollution-Driven Non-Communicable Diseases Adverse Health Effects

Risk drivers	• Industrial Emissions and Urbanization: Rapid urbanization and industrial activities release significant amounts of pollutants into the air and water. These emissions contain harmful substances like particulate matter (PM2.5), sulfur dioxide (SO2), and nitrogen oxides (NOx), which contribute to respiratory and cardiovascular diseases. Urban areas often face elevated pollution levels due to high traffic density and industrial concentration, leading to increased exposure to toxic pollutants. • Fossil Fuel Combustion and Energy Production: The burning of fossil fuels for energy production is a major source of air pollution, emitting greenhouse gases (GHGs) and other harmful pollutants. This combustion process releases carbon dioxide (CO2), methane (CH4), and black carbon, which not only contribute to climate change but also have direct health impacts, such as lung cancer and heart disease. The reliance on coal, oil, and natural gas exacerbates air quality issues, particularly in regions with poor regulatory controls. • Agricultural Practices and Pesticide Use: Intensive agricultural practices involve the extensive use of chemical fertilizers and pesticides, which can contaminate soil and water sources. These chemicals can enter the food chain, posing long-term health risks such as endocrine disruption, reproductive health issues, and certain cancers. Additionally, the use of nitrogen-based fertilizers contributes to the formation of ground-level ozone, a harmful air pollutant. • Waste Management and Chemical Disposal: Inadequate waste management practices lead to the accumulation of hazardous chemicals and pollutants in the environment. Improper disposal of industrial waste, electronic waste, and pharmaceuticals results in soil and water contamination. This exposure can cause neurological disorders, developmental issues, and other chronic health conditions. Effective waste management systems are crucial to minimize these health risks. • Climate Change and Environmental Degradation: Climate change exacerbates existing pollution-related health risks by altering weather patterns and increasing the frequency of extreme weather events. Rising temperatures can intensify the formation of ground-level ozone and increase the prevalence of heat-related illnesses. Additionally, climate change can affect the distribution of pollutants, leading to new exposure pathways and health risks. Understanding these drivers is essential for developing targeted interventions and promoting sustainable development. Addressing these risk drivers involves implementing policies that reduce emissions, promote clean energy alternatives, regulate agricultural practices, improve waste management, and mitigate the impacts of climate change. These efforts are critical to reducing the burden of pollution-driven NCDs and protecting public health.

Hazards triggering	• Air Pollution (e.g., PM2.5, NO2): Fine particulate matter (PM2.5) and nitrogen dioxide (NO2) are major air pollutants that significantly impact respiratory and cardiovascular health. Chronic exposure to these pollutants is linked to asthma, chronic obstructive pulmonary disease (COPD), heart attacks, and strokes. Air pollution is a leading environmental risk factor for premature mortality worldwide. • Chemical Pollutants (e.g., Lead, Mercury): Exposure to toxic metals such as lead and mercury can lead to serious health problems, including neurological damage, developmental disorders, and kidney disease. These pollutants can accumulate in the environment from industrial processes, improper waste disposal, and contaminated food and water sources. • Noise Pollution: Prolonged exposure to high levels of noise pollution, often from urban environments, can lead to stress-related health issues, such as hypertension, sleep disturbances, and mental health disorders. Noise pollution is increasingly recognized as a contributor to chronic health conditions, affecting both physical and mental well-being. • Urban Heat Islands: Urban areas often experience higher temperatures than their rural surroundings due to human activities and infrastructure. This phenomenon, known as urban heat islands, exacerbates heat-related illnesses, particularly during heatwaves, and can worsen air quality by increasing the formation of ground-level ozone. • Water Contamination: Contaminated water sources, often due to agricultural runoff, industrial discharge, and inadequate waste management, pose significant health risks. Pollutants in water can lead to gastrointestinal illnesses, reproductive health issues, and increased cancer risk. Ensuring clean water access is crucial for preventing these adverse health effects. These hazards contribute to the development and exacerbation of non-communicable diseases, highlighting the need for comprehensive environmental health strategies. Addressing these hazards involves implementing policies and practices that reduce pollution, enhance environmental monitoring, and promote sustainable urban and industrial development. By mitigating these environmental hazards, we can significantly reduce the burden of pollution-driven NCDs and improve public health outcomes.

Hazards triggered by	Hazards triggered by pollution-driven NCDs include increased morbidity and mortality rates, economic challenges, and social inequalities. • Public Health Crises Due to Increased Disease Burden: Pollution-driven NCDs, such as respiratory and cardiovascular diseases, lead to increased morbidity and mortality rates. This influx of patients strains healthcare systems, reduces their capacity to manage other health conditions, and necessitates greater healthcare resources and planning. • Economic Instability Due to Healthcare Costs and Productivity Losses: The rise in NCDs leads to increased healthcare costs for treatment and management, placing a financial burden on individuals and health systems. Additionally, reduced workforce productivity due to illness or premature death contributes to economic instability and decreased economic growth. • Long-Term Mental and Psychological Effects: Chronic exposure to pollution and associated health impacts can lead to increased mental health issues, such as anxiety, depression, and stress-related disorders. These psychological effects further strain healthcare services and impact individuals' quality of life and societal well-being. • Social Inequalities: Pollution disproportionately affects vulnerable populations, exacerbating existing social inequalities. Communities with limited access to healthcare, clean environments, and resources face greater health risks and challenges in managing NCDs, leading to disparities in health outcomes. • Environmental Degradation: The persistence of pollution-driven health issues underscores broader environmental degradation, impacting ecosystems and biodiversity. This can lead to a vicious cycle where environmental harm further exacerbates health risks, necessitating comprehensive environmental management strategies. These hazards highlight the wide-ranging impacts of pollution-driven NCDs, emphasizing the need for integrated approaches to environmental health, policy intervention, and public awareness. By addressing these challenges, we can work towards reducing the health and economic burdens associated with pollution and promoting a healthier society.

Cascading impacts	• Strain on Healthcare Systems: The increasing prevalence of pollution-driven NCDs places a substantial burden on healthcare facilities and personnel. This can lead to reduced care quality and increased mortality rates, as resources are stretched thin, potentially delaying treatment for other conditions like routine screenings and preventive care. • Reduced Economic Productivity: The health impacts of pollution-driven NCDs result in a less productive workforce due to illness and absenteeism. This contributes to economic downturns, business disruptions, and increased healthcare costs, affecting overall economic stability and growth. • Social and Health Inequalities: Pollution disproportionately affects marginalized and vulnerable communities, exacerbating existing social and health disparities. These inequalities may lead to differential access to healthcare, clean environments, and economic opportunities, further entrenching cycles of disadvantage. • Increased Mental Health Issues: The stress and uncertainty associated with chronic health conditions, environmental degradation, and economic instability can lead to a rise in mental health disorders, such as anxiety and depression, further impacting societal well-being and healthcare demand. • Disruption of Education: Health-related issues stemming from pollution can indirectly affect educational outcomes, as children and young adults may face illness-related absences, impacting their learning and future opportunities. Additionally, families burdened by health and economic challenges may deprioritize education. These cascading impacts underscore the need for integrated, multi-sectoral approaches to managing environmental health and reducing the burden of NCDs. Addressing these issues requires coordinated efforts across health, environmental, and economic sectors to promote sustainable development and health equity.
Compound relationships	• NCDs and social conflict: When social conflict occurs simultaneously with a high burden of NCDs, the crisis intensifies as conflict exacerbates the conditions for poor health outcomes. Conflicts disrupt healthcare systems, create overcrowded living situations, and lead to resource scarcity, making populations more vulnerable to NCDs. • NCDs and climate-related stressors: The growing severity of the climate crisis, marked by more frequent and intense extreme weather events, can lead to increased stress levels, poor mental health, and unhealthy behaviours, thereby accelerating the development of NCDs. Climate-related changes can create an environment that fosters the growth of risk factors like poor diet and physical inactivity. • NCDs and mis/disinformation: mis/disinformation often exacerbate public health crises related to NCDs. The spread of false information about disease prevention, management, and treatment can lead to confusion and undermine trust in health authorities. This mis/disinformation can result in harmful behaviours, such as ignoring evidence-based recommendations or using unproven treatments, which can worsen health outcomes. • Concurrent NCD epidemics: The simultaneous occurrence of multiple NCD epidemics (e.g., rising rates of diabetes and heart disease) in the same region can overwhelm healthcare systems and complicate public health responses, resulting in greater impacts than either epidemic would cause alone.

Illicit Drug Abuse, Trafficking, and Risk to Public Health

Risk drivers	• Technological Advancements: The internet and associated technologies (social media, cryptocurrencies, online marketplaces, etc.) have revolutionized drug trafficking, increasing accessibility, anonymity, and law enforcement challenges. • Shifting Security Landscape: Global conflicts, instability, weak governance, and organized crime networks significantly impact drug production, trafficking, and consumption. • Evolving Socioeconomic Conditions: Poverty, inequality, unemployment, and financial crises contribute to substance abuse, while globalization and illicit financial flows facilitate drug trade. • Demographic and Social Changes: Urbanization, aging populations, youth cultures, and demographic shifts influence drug use patterns and vulnerabilities within specific populations.
Hazards triggering	• Mental Health Issues: Individuals with mental health disorders, such as depression, anxiety, or trauma, are more likely to self-medicate with illicit substances. Additionally, genetic predisposition can also play a role in increasing the risk of substance abuse. • Socioeconomic Challenges: Economic hardship, social disadvantage, and lack of education can contribute to substance abuse as a coping mechanism. Limited knowledge about the risks and consequences of substance abuse can also increase the likelihood of use. • Social Problems: Peer pressure, lack of parental involvement, and social isolation can increase the risk of substance abuse especially in young people. Furthermore, easy access to illicit substances, homelessness, and history of incarceration can also contribute to the development of substance use disorders.
Hazards triggered by	• Health Problems: Illicit drug use can lead to severe physical and mental health consequences, including overdose, respiratory problems, infectious diseases, exacerbated depression, anxiety, psychosis, and increased risk of suicidal thoughts and behaviours. • Security Risks: Substance abuse can increase the risk of accidents, injuries, and violent behaviour, posing a threat to individual and public safety. • Legal and Financial Consequences: Illicit drug use can result in arrest, incarceration, financial problems, debt, and loss of assets, leading to long-term economic and social instability. • Social Consequences: The abuse of illicit drugs can lead to social isolation, marginalization, and the creation of ghettos, where substance use is concentrated and perpetuated, limiting opportunities for social mobility and rehabilitation.
Cascading impacts	• Health problems: Increased health care costs, transmission of infectious diseases, overdose and mortality, long-term consequences on physical and mental health. • Security risks: Increased crime rates, increased risk of accidents, pressure on law enforcement and emergency services. • Legal and financial consequences: Increased burden on the justice system, financial ruin, including debts, bankruptcy and loss of assets, decreased economic productivity, increased use of social services • Social consequences: social isolation and marginalisation and perpetuation of cycles of poverty, inequality and social disadvantage, as substance abuse can limit opportunities for education, employment and social mobility.

Compound relationships	• Infectious Disease Transmission: Drug abuse, particularly through injection, significantly increases the risk of transmitting infectious diseases like HIV/AIDS, hepatitis, and other blood-borne pathogens. • Overdose and Mortality: Overdose remains a leading cause of death related to drug abuse, posing a significant public health threat. • Exacerbated Mental Health Crises: Drug abuse can severely worsen existing mental health conditions and increase the risk of severe mental health crises, including psychosis and suicide. • Social and Economic Instability: Drug abuse contributes to social and economic instability through increased crime rates, reduced productivity, and strain on healthcare and social services. • Overburdening Healthcare Systems: Drug abuse-related emergencies, treatment needs, and the social consequences of addiction place a significant strain on healthcare systems and social services.;

Gaps and needs

	Operational	Research	Policy
Pathogens with high epidemic potential	1. Limited global health surveillance infrastructure for real-time data sharing and early warning systems. 2. Inadequate healthcare facilities and training for public health practitioners, particularly in genomic epidemiology. 3. Insufficient standardization in data analysis workflows, such as bioinformatics pipelines.	1. Limited funding for research and development on vaccines, treatments, and diagnostics. 2. Need for further development of novel surveillance mechanisms, such as event-based surveillance, wastewater surveillance, and genomic surveillance. 3. Requirement for increased investment in genomic epidemiology research and training for public health practitioners to enhance their ability to interpret genomic data.	1. Weak global governance framework to coordinate responses during health emergencies. 2. Lack of cross-sectorial and trans-disciplinary coordination for preparedness and response. 3. Inadequate communication and education strategies for the broader public, leading to misinformation and mistrust.

Antimicrobial Resistance (AMR)	1. Inadequate implementation of antimicrobial stewardship programmes (ASPs) in human health settings. 2. Limited use of clinical decision support systems (CDSS) for prescribers in human health settings. 3. Inadequate infection prevention and control (IPC) programmes in human health settings. 4. Insufficient biosecurity measures in animal health settings to prevent emergence and spread of infection. 5. Limited implementation of food safety compliance programmes in animal health settings. 6. Need for optimizing wastewater treatment to minimize spread of AMR 7. Need for improving waste management in agricultural Production. 8. Weak healthcare systems and inadequate infrastructure in low- and middle-income countries.	1. Need for further research on effective antimicrobial stewardship programmes (ASPs) and clinical decision support systems (CDSS) in human health settings. 2. Limited understanding of the impact of biosecurity measures on preventing emergence and spread of infection in animal health settings. 3. Requirement for more research on the development of new antimicrobials and alternative treatments to address AMR and for better understanding of the mechanisms of AMR and its transmission and evolution. 4. Limited development of effective vaccines and diagnostic tools for AMR. 5. Limited data on AMR prevalence, transmission and impact. 6. Need for improved surveillance and monitoring systems to track AMR trends and evaluate the effectiveness of interventions.	1. Weak regulation and supervision to prevent falsified and counterfeit antimicrobials in human health settings. 2. Inadequate regulation and supervision to promote prudent use of antimicrobials in animal health settings. 3. Lack of integration of vaccination programs within AMR National Action Plans to prevent infections leading to antibiotic use, and reduce the pressure for bacteria to develop AMR. 4. Insufficient international cooperation and coordination and implementation of AMR National Action Plans across EU Member States. 5. Limited public awareness and understanding of AMR.

Pollution-Driven Non-Communicable Diseases Adverse Health Effects	1. Inadequate data collection and analysis for NCD risk factors, including limited use of novel mechanisms such as electronic health records and mobile health applications. 2. Insufficient public health infrastructure and capacity for NCD management, including inadequate training for healthcare professionals. 3. Limited access to healthcare services, medication, and care for NCD patients, particularly in low- and middle-income countries. 4. Inadequate promotion of healthy lifestyles and nutrition education, contributing to high rates of NCDs. 5. Insufficient standardization of data analysis for NCD research and surveillance, hindering comparability and reproducibility of results.	1. Lack of comprehensive global governance framework to coordinate a clear response to NCDs, including inade-quate collaboration be-tween governments, in-ternational organizations, and civil society. 2. Insufficient funding and investment in public health infrastructure, re-search and development, and healthcare services for NCD management. 3. Limited policy integra-tion and coordination across sectors, including health, education, and social welfare, to address the social determinants of NCDs. 4. Inadequate policies and programs to pro-mote health equity and reduce stigma around NCDs. 5. Lack of clear and comprehensive commu-nication and education strategies to inform and engage the public on NCD prevention and management.	1. Need for further re-search on effective strategies for NCD pre-vention, management, and care, including inno-vative treatments and diagnostics. 2. Limited understanding of the social determi-nants of NCDs and their impact on health out-comes, requiring more research on addressing health inequities. 3. Requirement for more research on the effec-tiveness of different public health interven-tions and policies to re-duce NCD risk factors and improve health out-comes. 4. Need for improved surveillance and monitor-ing systems to track NCD trends and evaluate the effectiveness of inter-ventions. 5. Limited research on the economic burden of NCDs and the cost-effectiveness of differ-ent interventions, requir-ing more studies to in-form policy and invest-ment decisions.

Illicit Drug Abuse, Trafficking, and Risk to Public Health	1. Inadequate controls on the production, distribution, and sale of precursor chemicals, allowing for diversion into illicit channels. 2. Limited standardization of detection techniques and technologies for identifying and detecting illicit drugs. 3. Insufficient community-based initiatives, such as prevention programs and support groups, to build resilience and prevent drug abuse. 4. Limited access to education and economic opportunities, increasing the risk of addiction and drug abuse. 5. Inadequate promotion of healthy lifestyles and behaviours, such as regular exercise and healthy eating, to reduce the risk of addiction.	1. Need for further research on effective strategies for controlling the production, distribu-tion, and sale of precur-sor chemicals. 2. Limited understanding of the most effective community-based initia-tives and prevention pro-grams to build resilience and prevent drug abuse. 3. Requirement for more research on the impact of education and eco-nomic opportunities on reducing the risk of ad-diction and drug abuse. 4. Need for improved surveillance and monitor-ing systems to track drug abuse trends and evalu-ate the effectiveness of interventions. 5. Limited research on the effectiveness of promoting healthy life-styles and behaviours in reducing the risk of ad-diction and building resil-ience against drug abuse.	1. Lack of strict regulations and enforcement mechanisms to control the production, distribution, and sale of precursor chemicals. 2. Insufficient international cooperation and coordination to address the global nature of drug abuse and trafficking. 3. Limited funding and resources allocated to community-based initiatives and prevention programs. 4. Inadequate policies and programs to provide education and economic opportunities, particularly in vulnerable communities. 5. Lack of comprehensive national and international strategies to promote healthy lifestyles and behaviours and reduce the risk of addiction.

Policy reference and adaptation/mitigation measures

Pathogens with high epidemic potential

Adaptation measures in place	The European Union has implemented several adaptation measures to mitigate epidemic risks. Here are some key initiatives: 1. European Health Union: A framework aimed at strengthening health security across the EU, including improved coordination among Member States in preventing, preparing, and responding to human health hazards. 2. EU Health Emergency Preparedness and Response Authority (HERA): Established to enhance preparedness for future health emergencies by ensuring rapid access to medical countermeasures, including vaccines and treatments. 3. Strengthened surveillance systems: Implementation of the European Surveillance System (ECDC) to monitor infectious diseases and facilitate information sharing among Member States. 4. Emergency response coordination: Mandate of the Health Security Committee to coordinate responses to cross-border health threats and ensure timely communication among Member States. 5. Increased research and innovation funding: Investments through Horizon Europe for research on treatment and public health strategies. These measures reflect the EU's commitment to ensuring a coordinated and effective response to future epidemics.
Recommended adaptation measures	1. Enhance public health infrastructure: Ongoing investments in healthcare infrastructure and workforce training are priorities in the EU's public health strategies, aimed at ensuring readiness for future health emergencies. 2. Further strengthen integrated surveillance systems: The EU is investing in improving data sharing and surveillance systems through initiatives like the European Health Data Space and enhanced collaboration among HERA, the ECDC and other EU services. 3. Develop robust pandemic preparedness plans: The EU has committed to developing and regularly updating pandemic preparedness plans, incorporating lessons from past outbreaks to ensure effective responses. 4. Promote research and development: The Horizon Europe program supports R&D funding for health-related projects, including vaccine development and studies on infectious diseases, emphasizing public-private partnerships. 5. Foster transdisciplinary for effective One Health, to enable the analysis of pathogen transmission across humans, animals, and environments, and inform strategies for disease prevention and control. 6. Develop best practices to support open data sharing across institutions and agencies, both within and between countries, ensuring that data is easy to share, occurs along trusted channels, and is granular to accommodate security, safety and legal constraints. These measures are part of ongoing efforts to build resilience and enhance the EU's capacity to manage future epidemics effectively.

Mitigation measures in place	1. Structures and coordination at EU-level: Directoaret-General Health Emergency Preparedness and Response Authority (HERA): Established to enhance preparedness for future health emergencies by ensuring rapid access to medical countermeasures, including vaccines and treatments; ECDC: provides guidance to help countries prevent and respond to outbreaks and public health threats.; Health Security Committee (HSC): enables the exchange of information on health-related threats and sharing experiences on preparedness and response plans and crisis management strategies; EU Health Task Force: an initiative to support countries in Europe and around the world by providing operational outbreak response and crisis preparedness related to communicable diseases or diseases of unknown origin. 2. Vaccine procurement and distribution: Coordinated efforts to secure vaccines through the EU Vaccines Strategy, ensuring equitable access and distribution among member states. 3. Collaboration with international organizations: Engagement with the World Health Organization (WHO), its Hub for Pandemics and Epidemic Intelligence, and other global health entities to enhance collective resilience and information sharing. 4. Increased research and innovation funding: Investments through Horizon Europe for research on infectious diseases, vaccine development, and public health strategies. These measures reflect the EU's investments in preventing future epidemics.
Recommended mitigation measures	1. Enhance vaccination programs: The EU has established the EU Vaccines Strategy, which focuses on securing vaccines, ensuring equitable distribution, and promoting vaccination campaigns across member states. 2. Implement hygiene and infection control policies: The ECDC provides guidelines for hygiene and infection control, which Member States are encouraged to adopt in healthcare and public settings. 3. Strengthen international collaboration on health security: The EU actively collaborates with organizations like the World Health Organization (WHO) and engages in global health initiatives to coordinate responses and share resources during health crises. 4. Develop and maintain deployment platforms of open-source software and tools for analysis of data (such as those from genomics), ensuring that data analysis workflows are transparent, auditable, and reproducible. 5. Increase funding for infectious disease research: Through Horizon Europe, the EU allocates substantial funding for health research, including projects focused on infectious diseases, prevention strategies, and innovation in diagnostics and treatments. These initiatives reflect the EU's commitment to strengthening its health security framework and enhancing its capacity to mitigate future epidemic risks effectively.

Policy references	Each of the mentioned EU regulations and decisions contributes to the management and preparedness for health crises, including epidemics: 1. Regulation (EU) 2022/123: enhances the European Medicines Agency's (EMA) capability to prepare for and manage health crises through increased monitoring and coordination in the supply of critical medicines and medical devices during emergencies (European Parliament and Council, 2022c). 2. Commission Decision C(2021) 6712: established the Health Emergency Response Authority (HERA), which aims to strengthen the European Union's defence against serious cross-border health threats by ensuring the development, production, and distribution of medicines, vaccines, and medical devices (European Commission, 2021c). 3. Regulation (EC) No 851/2004: created the ECDC, an agency tasked with identi-fying, assessing, and communicating current and emerging threats to human health from communicable diseases (European Parliament and Council, 2004). 4. Commission Recommendation 2021/472: advises EU member states to imple-ment a common approach for monitoring SARS-CoV-2 and its variants in wastewater systems. It aims to establish a systematic surveillance network that can provide early warning of COVID-19 outbreaks and track the circula-tion of the virus within communities (European Commission, 2021d). 5. Regulation (EU) 2022/2371: addresses the management of serious cross-border threats to health, improving the EU's capacity to anticipate, prepare for, and respond to health crises through coordinated measures, information sharing, and emergency response (European Parliament and Council, 2022b). 6. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on a comprehensive approach to mental health: outlines a comprehensive approach to mental health, presenting a framework for action to promote mental wellbeing, prevent mental health issues, and improve access to mental health care across the European Union (European Commission, 2023d) 7. Scientific Advice Mechanism opinion on One Health: a comprehensive framework for integrating human, animal, and environmental health to address emerging health threats and promote a more holistic and sustainable approach to health policy in the European Union Each of these regulatory actions represents a step towards a more integrated and effective European health security framework, enhancing the collective ability to prevent, detect, and respond to complex health challenges.

Antimicrobial Resistance (AMR)

Adaptation measures in place	The European Union has implemented several adaptation measures to mitigate AMR risks: 1. EU Council adopted the Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach (Council of the European Union, 2023) 2. Established the EU One Health Action Plan against AMR (2017)) (European Commission, 2017). The plan outlines over 70 actions covering human health, animal health and the environment, whose progress is regularly monitored. 3. EC adopted EU Guidelines on the prudent use of antimicrobials in human health (European Commission, 2017b). The guidelines aim to reduce inappropriate use and promote the prudent use of antimicrobials in people. 4. ECDC Guidelines: Guidelines for infection control and antibiotic stewardship in healthcare settings (ECDC, 2020a). 5. European Antibiotic Awareness Day: An annual campaign to raise awareness about AMR and promote responsible antibiotic use (ECDC, 2020). 6. European Union Member States' One Health antimicrobial resistance (AMR) National Action Plans (NAPs) (ECDC, 2020b). 7. European Surveillance of Antimicrobial Consumption (ESAC): A network to monitor and analyse antibiotic consumption in Europe (ECDC, 2020c). 8. ECDC, EFSA and EMA have jointly established a list of harmonised outcome indicators to assist EU Member States in assessing their progress in reducing the use of antimicrobials and antimicrobial resistance (AMR) in both humans and food-producing animals ECDC, EFSA, and EMA, 2021). 9. AMR targets for AMR prevention and reduction are also tackled upon internationally, for example in the context of the Transatlantic Task Force on Antimicrobial Resistance (TATFAR), the UN Sustainable Development Goals and the G7 (TATFAR, 2020).. 10. EU Health Emergency Preparedness and Response Authority (HERA): Established to enhance preparedness for future health emergencies by ensuring rapid access to medical countermeasures, including vaccines and treatments. 11. EU research and innovation funding on AMR: EU4Health work programme 2023 specific action 'Support innovation and access to antimicrobials'; Horizon 2020 and the Horizon Europe programmes are key for the development, evaluation and implementation of measures against AMR (European Commission, 2023e). 12. Diagnostic Stewardship: Programs to promote responsible use of diagnostic tests and improve antibiotic prescribing (ECDC, 2020d). Worldwide several adaptation measures to mitigate AMR risks have been also imple-mented: The Global Antimicrobial Resistance and Use Surveillance System (GLASS) WHO launched the Global Antimicrobial Resistance and Use Surveillance Sys-tem (GLASS) in 2015 to continue filling knowledge gaps and to inform strate-gies at all levels. GLASS has been conceived to progressively incorporate data from surveillance of AMR in humans, surveillance of the use of antimicrobial medicines, AMR in the food chain and in the environment. GLASS provides a standardized approach to the collection, analysis, interpretation and sharing of data by countries, territories and areas,

	and monitors the status of existing and new national surveillance systems,with emphasis on representativeness and quality of data collection. Some WHO regions have established surveil-lance networks that provide technical support to countries and facilitate enrolment into GLASS (WHO, 2022). World Antibiotic Awareness Week: An annual campaign to raise awareness about AMR and promote responsible antibiotic use (WHO, 2020). Global Antibiotic Research and Development Partnership (GARDP): A part-ner-ship to develop new antibiotics and improve access to existing ones (GARDP, 2025) Antibiotic Stewardship Programs: Programs to promote responsible antibi-otic use and reduce antibiotic resistance in healthcare settings (CDC, 2024). Responsible Use of Antibiotics in Agriculture: Guidelines and regulations to promote responsible use of antibiotics in agriculture and reduce antibiotic re-sistance (WHO, 2018). Alternative Farming Practices: Practices such as organic farming and agroe-cology that reduce the need for antibiotics in agriculture (FAO, 2020) Wastewater Treatment: Improved wastewater treatment to reduce the re-lease of antibiotics and antibiotic-resistant bacteria into the environment (WHO, 2018a). Soil and Water Conservation: Measures to reduce the release of antibiotics and antibiotic-resistant bacteria into soil and water (FAO, 2020a).
Recommended adaptation measures	The EU Council Recommendation of 2023 foresees a number of forward looking adaptation measures to fight AMR in EU. Some of them are listed below: 1. A high level of cooperation between EU Agencies (European Food Safe-ty Authority (EFSA), ECDC and European Centre for Disease Prevention and Control (ECDC) and European Medicines Agency (EMA) should be reinforced and extended to include the European Environmental Agency (EEA) and the European Chemical Agency (ECHA), to ensure a coherent, One Health, evidence-based response to AMR 2. Member States cross-sectoral cooperation and stakeholders' involve-ment are crucial to ensure the full and effective implementation of One Health AMR policies and actions and it is proposed to enhance this cooperation, particularly through the EU AMR One Health Network. 3. The follow-up given to the 2017 EU One Health Action Plan against AMR and of the EU Council Recommendation of 2023 should be moni-tored regularly to measure progress towards achieving their objectives and identify gaps in the efforts to tackle AMR. 4. Enhanced international cooperation should take place, in particular in the context of the United Nations, G7, G20 and with the quadripartite organisations (the Food and Agriculture Organization of the United Na-tions (FAO), the United Nations Environment Programme (UNEP), the World Organization for Animal Health (WOAH) and the World Health Organization (WHO).

Mitigation measures in place **Recommended mitigation measures**	1. To address AMR effectively, the implementation of AMR actions within a One Health approach that considers human, animal, and environmental factors is crucial. 2. Enhancing AMR monitoring and surveillance systems such as the WHO GLASS system. 3. Promoting antibiotic stewardship programs to encourage the responsi-ble use of antibiotics. 4. Investing in research and development for new diagnostics, vaccines, antibiotics and alternative treatments to address the growing threat of AMR. 5. Strengthening of infection control and prevention measures in health-care settings to reduce the spread of AMR. 6. Improving access to antibiotics and other essential medicines, particu-larly in low- and middle-income countries. 7. Public awareness, education, and international collaboration are es-sential for combating AMR and preserving the efficacy of antibiotics for future generations. Collaborative and cooperative involvement of stakeholders in public, veterinary and ecological health sectors is fore-most to circumvent the problem effectively.
Policy references	1. EU Council Recommendation on stepping up EU actions to combat anti-microbial resistance in a One Health approach (Council of the European Union, 2023) 2. EU One Health Action Plan against AMR (2017) (European Commission, 2017) 3. Scientific Advice Mechanism on One Health: One Health Governance in the European Union (European Commisson, 2024c). 4. DIRECTIVE (EU) 2024/3019 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning urban wastewater treatment (recast)...moni-toring obligation for the presence of AMR in urban wastewater (Europe-an Parliament and Council, 2024d)

Pollution-Driven Non-Communicable Diseases Adverse Health Effects

Adaptation measures in place	These measures aim to reduce pollution exposure and mitigate health impacts, but continued efforts and collaboration are necessary for sustained progress. Various adaptation measures have been implemented to address the growing burden of NCDs: • National NCD control plans and policies • International agreements on tobacco control and healthy lifestyle promotion • Urban planning and green infrastructure initiatives to promote physical activity and mental well-being • Public health campaigns promoting healthy diets and lifestyles These measures aim to reduce the risk factors for NCDs and mitigate their health impacts, but continued efforts and collaboration are necessary for sustained progress. Countries and international organizations have implemented several adaptation measures to address NCDs. Here are some key initiatives: 1. National NCD control plans: Many countries have developed plans to address NCDs, which include policies and strategies to reduce risk factors such as tobacco use, physical inactivity, and unhealthy diets. 2. International agreements on NCD control: The World Health Organization (WHO) has established the Global Action Plan for the prevention and control of NCDs, which provides a framework for countries to address NCDs (WHO, 2013). 3. Urban planning and green infrastructure initiatives: Many cities have implemented urban planning initiatives to promote physical activity, reduce air pollution, and create green spaces. 4. Public health campaigns promoting healthy lifestyles: Public health campaigns have been implemented to promote healthy diets, physical activity, and mental well-being. 5. Increased funding for NCD research and innovation: Investments in research and innovation have been made to develop new treatments, diagnostics, and prevention strategies for NCDs. 6. Strengthened healthcare systems: Many countries have strengthened their healthcare systems to improve access to NCD care, including training healthcare professionals in NCD management. 7. Improved data collection and surveillance: Improved data collection and surveillance systems have been implemented to track NCD risk factors and trends, and to monitor the impact of NCD control measures. 8. Increased collaboration and coordination: International collaboration and coordination have been strengthened to address the global nature of NCDs, including the sharing of best practices and expertise. These measures reflect the commitment of countries and international organizations to addressing the growing burden of NCDs and promoting healthy lifestyles.
Recommended adaptation measures	Implementing these measures will support the transition to sustainable and healthy environments, reducing the burden of NCDs. 1. Invest in NCD research and innovation: The Horizon Europe program supports R&D funding for health-related projects, including prevention and management of NCDs, emphasizing public-private partnerships. 2. Enhance healthcare systems: Ongoing investments in healthcare infrastructure and workforce training are priorities in the EU's public health strategies, aimed at ensuring readiness for future NCD management challenges. 3. Develop robust NCD prevention and control plans: National NCD control plans should be developed and regularly updated, incorporating lessons from past NCD control efforts to ensure effective responses. 4. Promote education and awareness on healthy lifestyles: Public health campaigns and education programs should be implemented to promote healthy diets, physical activity, and mental well-being. 5. Foster transdisciplinary for effective One Health approach to NCDs: The One Health approach should be applied to understand the interconnections between human, animal, and environmental health factors contributing to NCDs. 6. Develop best practices to support open data sharing on NCD risk factors and trends: Data sharing and surveillance systems should be strengthened to track NCD risk factors and trends, and to monitor the impact of NCD control measures. 7. Enhance community resilience and adaptive capacity: Community-based programs should be implemented to promote healthy lifestyles, reduce NCD risk factors, and improve mental well-being. 8. Integrate health and nutrition policies for holistic NCD management: Policies and programs should be integrated to address the social determinants of health, including food systems, physical activity, and mental well-being. 9. Promote healthy food and clean water access: Initiatives should be implemented to increase access to healthy food and clean water, reducing the burden of NCDs. 10. Develop evidence-based policies for NCD control and management: Policies and programs should be developed based on scientific evidence, ensuring effective and efficient NCD control and management.

Mitigation measures in place	1. EU initiatives to reduce air pollution: The EU has implemented policies to reduce air pollution, including the implementation of the Clean Air Programme (European Commission, 2013a), which aims to improve air quality and reduce the impact of air pollution on human health. 2. International agreements on NCD control: The World Health Organization (WHO) has established the Global Action Plan for the prevention and control of NCDs, which provides a framework for countries to address NCDs (WHO, 2013). 3. Public health initiatives promoting pollution reduction: Public health initiatives have been implemented to promote pollution reduction and health protection, including education campaigns and community-based programs. 4. Research and innovation funding for NCD prevention: Investments have been made in research and innovation to develop new treatments, diagnostics, and prevention strategies for NCDs. 5. National NCD control plans: Many countries have developed national NCD control plans, which provide a framework for addressing NCDs and reducing the burden of pollution-driven NCDs. 6. Public education campaigns: Public education campaigns have been implemented to raise awareness about the risks of pollution and NCDs, and to promote healthy lifestyles and behaviours. 7. Implementation of clean energy and sustainable technologies: The implementation of clean energy and sustainable technologies has been promoted to reduce pollution and mitigate the impact of NCDs. 8. Strengthened healthcare systems: Healthcare systems have been strengthened to improve access to NCD care and management, including training healthcare professionals in NCD prevention and management.

Recommended mitigation measures	Advancing these measures is crucial for reducing pollution, protecting public health, and promoting sustainable development. 1. Implementing clean air and water policies: The EU has established policies to reduce air and water pollution, including the implementation of the Clean Air Programme (European Commission, 2013a) and the Water Framework Directive (European Parliament and Council, 2000). 2. Strengthening environmental regulations: The EU has strengthened enforcement mechanisms for environmental regulations, including the implementation of the Environmental Liability Directive (European Parliament and Council, 2004a). 3. Building capacity for pollution control and risk assessment: The EU has invested in building capacity for pollution control and risk assessment, including the development of tools and guidelines for pollution monitoring and assessment. 4. Enhancing cross-sectoral collaboration and stakeholder engagement: The EU has encouraged cross-sectoral collaboration and stakeholder engagement, including the establishment of the European Health Union and the European Observatory on Health Systems and Policies. 5. Promoting sustainable urban development and green infrastructure: The EU has promoted sustainable urban development and green infrastructure, including the implementation of the Urban Agenda for the EU (European Commission, 2016) and the European Green Deal (European Commission, 2019b). 6. Implementing education and awareness campaigns on pollution and NCD prevention: The EU has implemented education and awareness campaigns on pollution and NCD prevention, including the development of public health campaigns and community-based programs. 7. Developing and implementing policies for pollution reduction and NCD control: The EU has developed and implemented policies for pollution reduction and NCD control, including the development of national NCD control plans and policies. 8. Increasing funding for NCD research and innovation: The EU has increased funding for NCD research and innovation, including the allocation of substantial funding for health research through the Horizon Europe program.

Policy references	Each of the mentioned EU regulations and decisions contributes to the management and preparedness for health crises, including epidemics: 1. Regulation (EU) 2022/123: enhances the European Medicines Agency's (EMA) capability to prepare for and manage health crises through increased moni-toring and coordination in the supply of critical medicines and medical devices during emergencies (European Parliament and Council, 2022c). 2. Commission Decision C(2021) 6712: established the Health Emergency Re-sponse Authority (HERA), which aims to strengthen the European Union's de-fence against serious cross-border health threats by ensuring the develop-ment, production, and distribution of medicines, vaccines, and medical devices (European Commission, 2021c). 3. Regulation (EC) No 851/2004: created the ECDC, an agency tasked with identi-fying, assessing, and communicating current and emerging threats to human health from communicable diseases (European Parliament and Council, 2004). 4. Commission Recommendation 2021/472: advises EU member states to imple-ment a common approach for monitoring SARS-CoV-2 and its variants in wastewater systems. It aims to establish a systematic surveillance network that can provide early warning of COVID-19 outbreaks and track the circula-tion of the virus within communities (European Commission, 2021d). 5. Regulation (EU) 2022/2371: addresses the management of serious cross-border threats to health, improving the EU's capacity to anticipate, prepare for, and respond to health crises through coordinated measures, information sharing, and emergency response (European Parliament and Council, 2022b). 6. Communication from the Commission to the European Parliament, the Coun-cil, the European Economic and Social Committee and the Committee of the Regions on a comprehensive approach to mental health: outlines a compre-hensive approach to mental health, presenting a framework for action to promote mental wellbeing, prevent mental health issues, and improve access to mental health care across the European Union (European Commission, 2023d). 7. Scientific Advice Mechanism opinion on One Health: a comprehensive frame-work for integrating human, animal, and environmental health to address emerging health threats and promote a more holistic and sustainable ap-proach to health policy in the European Union (European Commission, 2024c). Each of these regulatory actions represents a step towards a more integrated and effective European health security framework, enhancing the collective ability to prevent, detect, and respond to complex health challenges.

Adaptation measures in place	1. Legislative framework: the development of drug policy and legislation is not at EU level, but at national level. Therefore, it is difficult to have a harmonisation of drug policy objectives. For example, Sweden is the most restrictive country, aiming at a drug-free society. The main common objectives are the fight against drug trafficking and the dealing with health and social effects. 2. Law enforcement: the Lisbon Treaty provides a legal basis for EU action in the fight against drugs. The Treaty on the Functioning of the EU (TFEU) highlights the judicial cooperation in criminal matters, the adoption of minimum rules concerning the definition of criminal offences and sanctions on serious crime with a cross-border dimension (e.g., drug trafficking), the establishment of measures to promote and support the action of Member States in the field of crime prevention, and the complementary competence of EU on public health issues, with a focus on drug demand reduction, prevention and harm reduction. 3. Prevention and harm reduction: the aim is to increase the access to opioid agonist treatment and syringe programmes to promote education and awareness, and increase the possibility for treatments and rehabilitation (e.g., opioid substitution therapy). 4. Research and innovation: the continuous introduction of new drugs in the market renders necessary drug monitoring and research. New and more sophisticated methods to assess and recognise drugs are needed. Research should focus analysis of data on emerging threats and new technologies regarding drug detection, interdiction, and treatment.
Recommended adaptation measures	1. Implement Alternative Development Programs: Support sustainable lives for communities affected by drug cultivation and trafficking, such as through crop substitution programs, vocational training, and infrastructure development. 2. Enhance Access to Treatment and Healthcare: Provide accessible and affordable treatment options for individuals affected by drug abuse, including medication-assisted treatment, counselling, and harm reduction services. 3. Promote Community-Based Initiatives: Support community-based initiatives that address the root causes of drug abuse, such as poverty, lack of education, and social inequality, through programs like job training, education, and social support.
Mitigation measures in place	The EU drugs strategy 2021-2025 (Council of the European Union, 2021) aims to tack-le drug-related security and public health challenges, reducing drug supply and de-mand among all actors and authorities at all the levels of EU . The main points are: 1. Drug supply reduction: prevention, dissuasion, and disruption of drug-related crime (organised crime) through law enforcement cooperation, interdiction, confiscation, and border management. 2. Drug demand reduction: prevention, early detection and intervention, rehabilitation, harm reduction, social reintegration, and recovery. 3. Address drug-related harms: measures to prevent or reduce the possible health and social risks for users and society in general. One aim is to reduce the incidence of drug-related infectious diseases.

Recommended mitigation measures	1. Technological Solutions and Continuous Monitoring: Implement advanced technologies to detect and track drug trafficking patterns, and establish a system for continuous monitoring and evaluation to adjust and refine mitigation measures as needed. 2. Enhance Border Controls: Strengthen border security through increased personnel, advanced technologies, and regular searches of high-risk cargo and vehicles. 3. Intelligence Gathering and Sharing: Establish a centralized intelligence hub to collect and analyse data on drug trafficking trends, routes, methods, and share intelligence with international partners. 4. Collaboration and Community Engagement: Strengthen partnerships with neighbouring countries, international organizations, and local communities to share best practices, gather information, and provide support and resources to affected individuals and families. 5. Capacity Building and Regulatory Measures: Provide specialized training for border officials and law enforcement agencies, enhance the capacity of forensic laboratories, and implement strict regulations on the transportation of controlled substances. 6. Shifting Health Challenges: Prevent and treat health outcomes related to drug abuse and trafficking.
Policy references	Some of the latest policy references include: - United Nations General Assembly Special Session (UNGASS) 2021: The UNGASS 2021 outcome document provides a comprehensive framework for addressing the world drug problem, including the abuse of illicit substances (United Na-tions General Assembly, 2021). - WHO Guidelines for the Psychosocially Assisted Pharmacological Treatment of Opioid Dependence: These guidelines provide evidence-based recommenda-tions for the treatment of opioid dependence, including medication-assisted treatment and psychosocial interventions (WHO, 2009). - UNODC-WHO International Standards for the Treatment of Drug Use Disor-ders: These standards provide a comprehensive framework for the treatment of drug use disorders, including the abuse of illicit substances (UNODC and WHO, 2020). - European Union's Agenda and Action Plan on Drugs 2021-2025: This policy reference provides a comprehensive framework for addressing the abuse of illicit substances within the European Union, including harm reduction, preven-tion, and treatment (European Commission, 2020a). - WHO Global Health Sector Strategy on HIV, Viral Hepatitis and Sexually Transmitted Infections 2022-2030: This strategy provides a comprehensive framework for addressing the intersection of HIV, viral hepatitis, and sexually transmitted infections with the abuse of illicit substances (WHO, 2022).

Environmental

Environmental risks six risks, air pollution, eutrophication, marine chemical pollution, marine macrolitter, marine microlitter and loss of biodiversity.

Brief introduction is provided below for some of the risks covered in this category.

Eutrophication

Human-induced eutrophication is caused by the excess input of nutrients (nitrogen and phosphorus) into aquatic ecosystems (e.g., lakes, rivers, coastal) that results in high rates of primary productivity, with adverse effects on the ecosystems and water quality degradation. Nutrient enrichment may cause accelerated algal growth with changes in species composition, abundance and biomass of phytoplankton and macrophyte communities. Harmful Algal Blooms (HABs) cause harmful effects on marine organisms and humans (e.g., through the release of toxins). The consequent decay of algae can cause oxygen depletion in the water, and further impact biodiversity, with the change and loss of benthic communities, and in extreme cases the occurrence of massive fish kill events. Human activities responsible for the excess input of nutrients (nitrogen and phosphorus) into aquatic ecosystems include agriculture, urban and industrial wastewater discharges, aquaculture, as well as industrial and transport air emissions of nitrogen oxides (NOx) and ammonia (NO3) that then undergo atmospheric deposition in coastal waters (Ibisch et al., 2016).

Marine chemical pollution

Marine chemical pollution is the contamination of the marine environment by synthetic or naturally occur-ring substances that originate from anthropogenic sources. Marine chemical pollution is a chronic phe-nomenon but can also manifest as acute pollution events (spills). Mineral oil (crude oil and refined petro-leum products with high content of aromatic hydrocarbons, PAHs) is often released due to tanker/other vessel accidents, leaks, and activities of offshore installations. Mineral oil can spread quickly on water (sub)surfaces, contaminating large areas, severely impacting seabirds, marine mammals, turtles and fish (Peterson et al., 2003). Long-term exposure to oil can cause carcinogenic effects and endocrine disruption also in humans (Laffon et al., 2016) . Hazardous and Noxious Substances (HNS) spills involve a wide range of toxic, corrosive, or reactive chemicals, including industrial chemicals, pesticides, solvents, and met-als/metalloids. These substances can cause immediate, severe impacts like acute poisoning of marine or-ganisms, destruction of coastal habitats, and contamination of seafood, thereby disrupting marine ecosys-tems and their services (Johnston et al., 2015). Many HNS are persistent, bioaccumulative, and biomagni-fying, meaning that their effects can be long-lasting and their concentrations magnified up food webs, contributing to chronic pollution and thus posing long-term risks to both wildlife and humans. Unlike most types of oil, many chemicals do not float on the surface, making them harder to detect and clean up.

Marine macro and micro litter

Marine litter is commonly defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. The presence of marine litter has harmful effects on the environment, marine organisms, economic effects. Macrolitter refers to large pieces of litter, larger than 2.5 cm, made of plastics and other materials like metal, glass, rubber, and textiles. Marine microlitter is commonly defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment of particles below 5 mm in in length. Microlitter is ubiquitous to marine ecosystems and is predominantly made of plastic. The presence of marine microlitter has also harmful effects on the environment, potential ability to accumulate in some marine organisms, economic effects and potentially harmful on human health.

Biodiversity loss

Biodiversity corresponds to the variety among all living organisms on Earth and the ecological complexes of which they are part of: this includes diversity within species, between species and of ecosystems. Besides having an intrinsic value, biodiversity is a vital asset for human societies as it provides essential services for human existence and well-being (Millenium Ecosystem Assessment, 2005). This includes provisional services (e.g. provision of food, medicine, and energy), regulation services (e.g. regulation of climate, air quality, and water quality) and cultural services (e.g. spiritual, recreational

and educational). Currently, unsustainable use of natural resources is driving biodiversity to decline worldwide faster than at any time in human history, putting at risk current and future delivery of essential services for human existence and well-being (IPBES, 2019).

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Air pollution	Yes	Yes	Yes	Yes
Eutrophication	Yes	No	Yes	No
Marine chemical pollution	Yes	Yes	Yes	Yes
Marine macrolitter	Yes	Yes	Yes	No
Marine microlitter	Yes	Yes	Yes	No
Biodiversity loss	Yes	Yes	Yes	Yes

Air pollution is a cross-border and emerging risk in Europe. Air pollutants are also short-lived climate forcers. It is essential to improve their knowledge and include them in climate scenarios. It is also relevant to evaluate co-benefits and trade-offs with climate scenarios (e.g. burning biomass may deteriorate air quality). Climate scenarios will impact meteorology then impacting air quality. Extreme events in terms of high temperature can cause high ozone concentrations, having impact on vegetation and human health. In case of very low winter temperature and stable atmospheric conditions, particulate matter emissions can accumulate and cause high pollution concentrations, which is why air pollution is also considered a high impact, low probability risk.

Eutrophication is recognised as a cross-border risk since nutrients, and consequently eutrophication events, can spill over along lakes, rivers and the coast and across borders into neighbouring countries. For example, the Baltic Sea, which is shared by eight EU countries, is heavily affected by eutrophication, with excess nutrient in-puts from agricultural runoff, sewage, and industrial activities that spill over borders and along the ma-rine waters. Eutrophication is a well identified and studied phenomena since the 1950s. Nutrient conditions in surface freshwaters have improved in recent decades (EEA, 2024), and EU marine areas affected by eu-trophication stayed stable over the last decade (EEA, 2025), due to the implementation of measures under EU policies such as the Water Framework Directive, Nitrates Directive, and Urban Wastewater Treatment Directive, and the Marine Strategy Framework Directive. Climate change is predicted to impact the eutroph-ication status of EU freshwater (Grizzetti et al., 2022) and marine waters (Polimene et al., 2024), with en-closed/semi closed basins (Black Sea, Mediterranean, and Baltic Sea) being more affected (Polimene et al., 2024). However, these impacts can be both positive and negative, and highly variable across geographical locations within each sea basin (Polimene et al., 2024). Water scarcity may drive freshwater scarcity, with a decrease in nutrient loads and marine productivity (Macias et al., 2025), while the reduction in sea ice cover could negatively impact eutrophication indicators in the Baltic Sea (Parn et al., 2024). The predicted decrease in salinity and increase in surface temperature may potentially lead to the offshore extension of the HAB habitats (Duteil et al. 2024). The evolution of eutrophication status will also depend on the nutri-ent reduction measures that may be taken under different management and policy scenarios (Grizzetti et al., 2017, Grizzetti et al., 2022; Friedland et al., 2021).

Marine chemical pollution: Marine spills can spread easily and widely in the marine environment, with deleterious effects that can be wide-ranging and long-lasting. Many past mineral oil spill accidents involved and had deleterious effects on multiple countries, e.g., in European waters, the Erika ccident, the Prestige accident, or at the international level, the Deepwater Horizon disaster[93] Marine spills are a familiar risk but can be considered emerging because:

93 See the Cedre association website for a compilation of spill cases: *https://wwz.cedre.fr/en/Resources/Spills*

- they can be difficult to foresee, and harm depends on several factors (environmental and socio-economic);
- newly used chemicals/elements will increase in demand, transport and thus spill risk at sea (e.g., lithium, cobalt, rare Earth elements). (Chang, 2014).

Climate change will likely impact some of the drivers of marine spills, e.g., the frequency and intensity of extreme events. It will also impact the effect of spills on ecosystems (less resilient ecosystems might be more vulnerable to spill damage) or the effectiveness of cleanup operations (e.g., mineral oil and dispersant are sensitive to temperature). Climate change can also indirectly affect coastal/offshore infrastructure and vessel traffic (e.g., decrease in ice cover will enable more ship traffic in the Arctic), thus changing spill risks. Complex changes in climate scenarios Risk analysis and spill response planning should be reviewed periodically. (Nordam et al 2017, Dong et al, 2022)

Marine spills have the characteristics of HILP risk events, due to the complexity of hazards they can cause and potential for long-term effects on ecosystems and economies at different scales (national, international).

Marine macrolitter has a transboundary nature which means that the input or the pollution generated in one country can crosses borders via ocean currents (e.g. Macias et al., 2019; Macias et al., 2022). Marine macrolitter is considered an emerging risk due to the increasing plastic production, slow degradation rates, the fragmentation into microplastic, accumulation on different environmental compartments (Hanke et al., 2025), and the economic impact. Extreme weather events and other climate-scenario phenomena (e.g., changes in ocean currents, etc.) can favour the input, distribution and accumulation of marine litter. Ma-rine macrolitter is persistent in the coastal and marine environments with continuous inputs that cause ecological damage, poses a threat to marine wildlife (Werner et al., 2016), and cause economic losses. Extreme events can also increase the impact at specific spatial scales. The implementation of measures under EU policies such as the Water Framework Directive, Urban Wastewater Treatment Directive, the Port Reception Facilities and the Marine Strategy Framework Directive have improved macro litter conditions on EU coastlines (Hanke et al., 2025).

Marine microlitter can be considered as a transboundary issue as ocean currents and atmospheric transport distribute microlitter particles. In addition to the factors considered for marine macrolitter, chemical additives leaching out of microlitter can potentially have toxic effects on marine life (Werner et al., 2016). Extreme weather events and other climate-scenario phenomena (e.g., changes in ocean currents, winds, etc.) can favour the input and distribution of marine litter. Microlitter, due to its pervasive presence, continuous input, and persistence, poses a high probability of widespread ecological harm, potential human health risks, and long-term nature of its impacts.

Biodiversity loss is an emerging risk based on the criteria “difficult to foresee”, i.e. it is difficult to assess the probability that a certain consequence will occur at a specific time / place / condition. Climate plays a critical role in biodiversity loss by influencing ecosystem stability, habitat conditions and species' distribution, reproduction, ability to feed, and survival. Different potential climate-related scenarios would lead to diverse outcomes as regards biodiversity-related risks. Some examples can be provided when considering different narratives in terms of climate and biodiversity conservation actions. E.g. a worst-case scenario (high emissions, no conservation efforts), characterized by severe global warming and extreme weather events might lead to mass extinctions particularly in most vulnerable ecosystems; altered species interactions and pollution causing pollinator loss, along with ecosystem degradation, could entail a collapse in economic sectors such as agriculture. A moderate scenario could lead to a certain degree of species adaptation but still population decline/ habitat degradation could occur. A best-case scenario could lead to ecosystem restoration, also due to conservation efforts at global level.

Beyond climate scenarios, specific local and global biodiversity scenarios integrating environmental, climatic, and socioeconomic trends are key to assess dynamically nature-related risks, and therefore to inform mitigation and adaptation strategies. Developing exhaustive biodiversity scenarios is signif-

icantly challenging due to the inherent complexity and non-linearity of natural processes. Biodiversity scenarios must also account for highly dynamic and interdependent biological, ecological, and socio-economic factors, and capture indirect impacts and contagion channels. Hence, the need to consider a 'local-global trade-off' and the need to account for nature-related risks using multiple metrics, among other.

Biodiversity loss may be classified as HILP risk due to a certain degree of uncertainty as regards timing, location, and triggers. In particular, when considering:

i. time horizon of risk materialization: some biodiversity risks might be more likely to unfold over long periods, potentially making immediate feedback loops less unlikely in the short term,

ii. heterogeneity in terms of geographical/ sectorial impact: although some economic activities/ geographies are highly exposed to biodiversity risks, others might be subject to hazards occasionally or in unpredictable ways,

iii. non-linear systematic effects: biodiversity risk probability might be perceived as low in the short term due to the difficulty in predicting tipping points for ecosystems, although once the critical threshold is crossed, the collapse could abruptly happen,

iv. localized/ unpredictable triggers: some severe consequences of biodiversity loss might be rare but catastrophic when they occur

Loss, damages, and potential impacts

Air pollution	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	High	High
Potential impact (next 10 years)	High	High	High	High

Amount of **losses and damages** over the past 10 years: around 300.000 premature deaths/year in EU...direct effects on "reduced activity days" and "hospital admissions". Impacts on vegetation, as crop production loss and N deposition reducing biodiversity. In the last 10 years in EU27 the mortality attributable to air pollution is approx. 190 K premature deaths per year (decreasing) while for the entire Europe (43 countries) the figures are approx. 350 K premature deaths. Monetization of the direct impacts presented previously: the costs of premature death attributable to air pollution in the last decade are in the range 2,000 - 2,200 Bn Euro/year (Third Clean Air Outlook; European Commission, 2022b). .

Under the current legislation scenario, the potential impacts, e.g. the premature mortality attributable to air quality is expected to remain between 130 and 140 K deaths in 2030 - 2050 in EU 27 and between 270 - 290 K in the European continent. The costs of premature deaths attributable to air pollution in the next decade are in the range 1,100 - 1,600 Bn Euro/year (Third Clean Air Outlook; European Commission, 2022b).

Data collection:

- Impact on health – European Air Quality Portal[94];
- GBD website[95]

Level uncertainties: N/A

94 EEA, European Air Quality Portal, *https://eeadmz1-cws-wp-air02.azurewebsites.net* (2025)

95 Global Burden of Disease Collaborative Network, Global Burden of Disease Study Data Resources, Seattle, United States: Institute for Health Metrics and Evaluation (IHME), *https://www.healthdata.org/research-analysis/gbd-data* (2024)

We can provide an uncertainty level for emission estimation, concentration and impacts, based on literature or our work. WHO also defines uncertainties linked to various health impacts. We can provide 95% Confidence Interval for premature mortality.

Eutrophication	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	N/A	High	Medium	N/A
Potential impact (next 10 years)	N/A	High	Medium	N/A

Direct impacts: Changes in species composition, abundance, and biomass of phytoplankton and macrophyte communities, changes and losses of benthic communities, including macrophytes, benthic invertebrates and fish. Oxygen depletion and water quality degradation.

If populations are not informed in time by public authorities, toxic harmful algal blooms can also have an impact on human health. Effects can include skin rashes, respiratory problems due to toxin inhalation, or food poisoning due to the consumption of seafood contaminated with algae toxins (e.g., paralytic shellfish poisoning). Each country usually has a monitoring in place for detecting these blooms, banning shellfish capture and avoiding consumption of contaminated seafood (e.g. Portugal[96]).

Indirect impacts: The occurrence of harmful algal blooms can lead to bans on aquaculture and shellfish harvesting to pro-tect consumers from contaminated seafood, and in some cases to high mortality of fish commercial spe-cies. The unpleasant visual effect (the water becames like a "green soup") can affect recreational activities and tourism. On top of that, economic losses include costs of restoring degraded ecosystems and imple-menting measures to mitigate eutrophication.The recent Oder River disaster is an example of a cross-border toxic algal bloom. The algal bloom was enabled by high nutrient concentrations combined with other factors, such as changes in salinity and drought (Free et al., 2023). The event originated in Polish waters but spread downstream into German waters causing the death of approximately 360 tonnes of fish and with an ecological impact that extended along 500 km of the river (Free et al., 2023). For **potential impacts**, it is the same as in the past events, and further exacerbated by climate change in some geo-graphical areas (Polimene et al., 2024).

Data collection:

Eutrophication indicators (e.g., chlorophyll, nutrients, dissolved oxygen, harmful algal blooms) databases and assessments:

- Marine Strategy Framework Directive and Water Framework Directive assessments[97]
- EEA Waterbase – Water Quality ICM[98]
- EMODnet Chemistry[99]
- Copernicus Marine Service (CMEMS) in situ and satellite products[100]
- ICES data portal[101]

96 The Portuguese Institute for Sea and Atmosphere: *https://www.ipma.pt/pt/bivalves/index.jsp*

97 WISE Water Information System for Europe, *https://water.europa.eu/*

98 EEA, Waterbase – Water Quality ICM: *https://www.eea.europa.eu/en/datahub/datahubitem-view/fbf3717c-cd7b-4785-933a-d0cf510542e1*

99 EMODnet Chemistry Portal, *https://emodnet.ec.europa.eu/en/chemistry*

100 Copernicus Marine Data Store: *https://data.marine.copernicus.eu/products*

101 ICES Data Portal: *https://data.ices.dk*

- Regional Sea Conventions assessments, such as OSPAR[102] and HELCOM[103] eutrophication assess-ments

Level uncertainties: Medium.

Uncertainty is high due to uncertainty of future impacts of climate change, complexity of the systems, and variability in nutrient inputs.

Marine chemical pollution	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium	High	High	High
Potential impact (next 10 years)	Medium	Medium	High	High

Direct loss/damage to infrastructure is usually minimal and could involve ships or buildings on the coast. Economic losses in terms of chemical spilled can be high, and depend on the nature of the substance. Direct human losses consequential to spills are usually rare, with fatalities being mostly associated with the causes of the spill (e.g., well blowout, vessel accidents, and weather conditions). However, prolonged or intense exposure to mineral oil and other toxic substances can lead to acute poisoning/death. Environmental damage of spills range from minimal to dramatic, depending on several factors linked to the characteristics of the spill, the receiving environment and weather conditions. Direct effects on ecosystems include mortality and/or long-term health effects of marine biota and habitat destruction.

Indirect effects include bans on aquaculture and shellfish harvesting to protect consumers from contaminated seafood. Disruption of tourism and recreational activities. Potential high mortality of larval stages of fish commercial species, with delayed long-term effects on stocks. Cleanup and containement operations can be very costly for mineral oil spills. Long-term health effects in humans (e.g., cancer, neurological effects, endocrine disruption) and ecosystems. Cleanup operations can also have deleterious effects on ecosystems (Beyer et al., 2016).

Potential impacts are similar to past events.

Overall, it is difficult to predict future potential impact of marine spills, due to the diversity of factors involved (e.g., energy demand, transition to renewable energy, advances in shipping and pipeline technology, policy enforcement, climate-related risks), which could lead to a mixed picture (some factors increasing risks, others reducing them). Thus, no drastic change is foreseen.

Data collection:

At EU level, there are different reporting commitments for spills of chemicals (mineral oil and HNS): the Marine Strategy Framework Directive (European Parliament and Council, 2008) (no database yet, but EMODnet Chemistry have some EU data), the Ship-Source Pollution Directive (European Parliament and Council, 2024e) (upcoming database hosted by EMSA). At the (sub)regional level, there are reporting com-mitments under Regional Sea Conventions such as OSPAR, the Bonn Agreement[104], HELCOM (e.g., reporting of accidental spills from offshore oil and gas installations, aerial surveillance reports of spills of any source). At the international level, Contracting Parties report spills of oil and

102 OSPAR Commission, Eutrophication assessments, *https://www.ospar.org/work-areas/hasec/eutrophication*

103 HELCOM, Eutrophication assessments, *https://helcom.fi/baltic-sea-trends/eutrophication/*

104 Bonn Agreement: *https://www.bonnagreement.org/*

HNS to the International Mari-time Organisation under the International Convention for the Prevention of Pollution from Ships (MARPOL) (International Maritime Organization, 2025). ICES database on contaminant concentrations in marine ma-trices and contaminant biological effects[105]. ITOPF also records accidental spills of, mainly, mineral oil but also other substances[106]. Interesting records of spill cases can be found on the Cedre website[107] and Ciimar website[108].

Level uncertainties: High

Large uncertainty due to future impacts of climate change, energy demands, availability and use of safe alternatives for chemicals.

Marine macrolitter	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	Medium to High	Medium to High	N/A
Potential impact (next 10 years)	High	Medium to High	Medium to High	Medium to High

Direct losses/damages:

- Fisheries: entanglement of marine life and potential damage to fishing gears. Reduction of catches.
- Aquaculture: operations can be affected by litter.
- Transport/shipping: marine litter can damage propellers, intake pipelines and other equipment.
- Coastal/beach management: Clean-up efforts, waste management and infrastructure maintenance.
- Tourism: Marine litter, particularly on beaches and in coastal areas, deters tourists, leading to revenue loss for the tourism industry.
- Loss of Biodiversity and ecosystem integrity (e.g., degradation of habitats, potential disruption of food webs, etc.);
- impact on human well-being (e.g., loss of aesthetic value of coastal areas and beaches, loss of recreational and cultural values)

Indirect losses/damages:

- Impacts on Ecosystem Services (e.g., coastal erosion)
- Impacts on Human Activities and Economy (e.g. potential reduction of fisheries productivity, potential increase of costs for some industries)

Potential impacts are generally the same as in the past events above. However, there are other potential impacts on ecosystems services: carbon sequestration and the potential disruption of sea nutrient cycling.

Data collection:

- Marine Strategy Framework Directive and Water Framework Directive assessments.

105 ICES database: *https://data.ices.dk/view-map?theme=201831*

106 Data and statistics on oil and chemical spills, *https://www.itopf.org/knowledge-resources/data-statistics/*

107 Cedre, Compilation of spill cases, *https://wwz.cedre.fr/en/Resources/Spills*

108 CIIMAR, HNS Spill Database, *https://www.ciimar.up.pt/hns/*

- EMODnet: spatial distribution and abundance of coastal and seafloor marine litter items.
- AOMI (Atlas of Ocean Microplastics) [109]
- AWI LitterBase scientific literature [110]

Level uncertainties: Medium

Challenge in accurate quantification, distribution, and degradation rates.

Marine microlitter	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	N/A	High	Medium to High	N/A
Potential impact (next 10 years)	N/A	High	High	Medium to High

Direct losses/damages:

- Impacts on Fisheries and Aquaculture: reduced seafood market value.
- Impacts on Water Treatment: increased water treatment costs
- Increased Production Costs: food and cosmetic product processing.
- Damage to Industrial Equipment: e.g., damage to intake pipelines, etc.
- Loss of Biodiversity and ecosystem integrity (e.g., degradation of habitats, potential disruption of food webs, etc.),
- Impact on human well-being (e.g., loss of aesthetic value of coastal areas and beaches, loss of recreational and cultural values)

Indirect losses/damages:

- Impacts on Ecosystem Services (e.g., coastal erosion)
- Impacts on Human Activities and Economy (e.g. potential reduction of fisheries productivity, potential increase of costs for some industries, potential impact on food security, etc.).

Potential impacts are generally the same as in the past events above. However, there are other potential impacts on ecosystems services: carbon sequestration and the potential disruption of sea nutrient cycling.

Data collection:

- EMODnet: spatial distribution and abundance of coastal and seafloor marine litter items.
- OSPAR Beach litter dataset [111]
- ICES seafloor macrolitter trawling data .[112]
- AWI LitterBase scientific literature.

Level uncertainties: High

109 Atlas of Ocean Microplastics database: *https://aomi.env.go.jp/Map?map=gmap_survey_point*

110 LitterBase scientific literature database: *https://litterbase.awi.de/*

111 OSPAR Beach Litter Dataset, ODIMS: *https://odims.ospar.org/en/maps/?layers=ospar_outer_boundary_2023_01_001,ospar_median_total_counts_beach_2022_05_001,ospar_inner_boundary_2016_01_002*

112 ICES Seafloor Macrolitter Trawling Data, *https://ices-library.figshare.com/articles/report/ICES_Manual_for_Seafloor_Litter_Data_Collection_and_Reporting_from_Demersal_Trawl_Samples/21435771*

Challenges in accurate quantification and distribution, limited understanding of their long-term fate, behaviour, and complex interactions within marine ecosystems and potential human health impacts. Improved detection techniques and extensive interdisciplinary research are needed.

Biodiversity loss	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	High	High
Potential impact (next 10 years)	High	High	High	High

Direct impacts:

Although it is difficult to get an estimate of **direct economic loss** due to biodiversity loss, some partial estimates exist. For instance, the InvaCost project estimated that the cost of biological invasions, one of the direct drivers of biodiversity loss, is estimated at US$140.20 billion (or €116.61 billion) between 1960 and 2020 in Europe only (Haubrock et al., 2021). The global assessment report on biodiversity and ecosystem services (Brondízio et al., 2019) also highlights economic impacts of illegal logging in European forests that cause revenue losses for states and, in some cases, private forest owners.

Globally, most of the >50 indicators used to assess past trends in biodiversity since 1970 show a net deterioration (see Chapter 2 in Brondízio et al., 2019). This holds true for indicators documenting ecosystem structure (the distribution of natural ecosystems on Earth), community composition (assemblage of plant, animal and other species that are interacting in a unique habitat), species populations (abundance and distribution of a species' population), organismal traits (characteristics of plant and animal species describing how they uptake, use and allocate resources), and genetic composition (diversity in genes within and between species). For instance, natural ecosystems have declined by 47% on average, relative to their earliest estimated states; the abundance of naturally-present species has declined by 23% on average in terrestrial communities; and the global biomass of mammals has fallen by 82%. At EU level, the decline in population abundance for some species is well monitored through two indicators: the Common bird index, which has been in continuous decline between 1990 and 2022 (-13.8%), and the Grassland butterfly index, which has declined by 32% over the last decade.

The **(potential) economic impact** of the decline in biodiversity has been estimated at > USD 2,7 trillion per year by 2030 (World bank, 2021). Consequently, biodiversity loss is in the top three global risks over the coming decade, together with extreme weather events and critical change to Earth systems.
According the global assessment report on biodiversity and ecosystem services (Brondízio et al., 2019), biodiversity (measured as species richness) is projected to further decline in most scenarios of global change in the coming decades.

Indirect impacts:

it is difficult to get an estimate of **indirect economic loss** due to decline in ecosystem services, the decline of such ecosystem services has an economic cost. For instance, if air and water quality are not regulated anymore, money will be spent to reach sufficient quality for human consumption (e.g artificial purification) and/or in health costs related to the treatment of affections related to the exposure to polluted air and/or the consumption of bad quality water.

The observed declines in biodiversity have resulted in declining regulation and non-material ecosystem services: while more food, energy and materials than ever before are now being supplied to people in most places, this frequently undermines nature's many other contributions such as pollination,

regulation of air and freshwater quality, and learning from indigenous and local knowledge. Importantly, the population of Europe uses more natural resources than are produced within the region, and depends on net imports of natural resources. Some of these imports negatively affect biodiversity and ecosystem services in other parts of the world. This is why the assessment of biodiversity loss at the EU level and within EU countries should not only consider the EU territories but encompass the entire globe.

The economic losses due to the decline or disruption of ecosystem services are immense and hard to quantify overall.

Some specific examples of **potential economic losses** due to decline in ecosystem services are shown below:

- The loss of natural buffers like wetlands and forests increases vulnerability to disasters such as floods and landslides. E.g., landslides cost the Italian economy between €1-2 billion per year, with some estimates reaching up to €600 million per event (The State of Soil in Europe, Jones et al., 2012).
- Soil degradation and agricultural productivity: the total cost of soil degradation, including erosion and loss of organic matter, could be up to EUR 38 billion annually for EU (The State of Soil in Europe, Jones et al., 2012)
- Pollinator loss alone could result in an estimated economic decline ranging from $235 billion to $577 billion in global crop output annually (IPBES assessment report on pollinators, pollination, and food production, 2016).
- The annual economic damage of ocean-acidification-induced coral reef loss by 2100 has been estimated to be US$500 to 870 billion depending on the level of CO2 emissions scenarios , and the corresponding global economic loss of shellfish production due to ocean acidification is estimated to be US$6-10 billion US$ per year (Brondízio et al., 2019)

The decline or disruption of ecosystem services also increases financial vulnerability:

- of the system: approximately 75% of corporate loans in the euro area are extended to companies highly dependent on ecosystem services. Degradation of these services can impair companies' ability to generate revenue and repay loans, posing systemic risks to the financial sector. (ECB, 2023)
- of the non-financial corporations: approximately 72% of non-financial corporations in the euro area are critically dependent on ecosystem services. Consequently, 75% of all corporate loans are exposed to nature-related risks (ECB Economic Bulletin, Issue 6/2024a)
- of countrie: across 26 countries for which a tipping point scenario consisiting on partial collapse of some ecosystems was considered, a downgrade of credit ratings was observed, which would increase the annual interest payment on debt by up to $53 billion a year, leaving many developing nations at significant risk of sovereign debt default (WEF/University of Cambridge report, Agarwala et al., 2022).

Some studies have also quntified the cost of inaction, i.e. the cost of not fighting decline in ecosystem services, and indicate that ecosystem services collapse would cause annual losses estimated at USD 2.7 trillion by 2030 (World Bank, 2020)/ about 2.3% of global GDP annually by 2030 (Johnson et al., 2021).

According the global assessment report on biodiversity and ecosystem services (Brondízio et al., 2019), provisional services (food, feed, timber and bioenergy) are expected to increase while regulating services (nitrogen retention, soil protection, crop pollination, crop pest control and ecosystem carbon storage and sequestration) are expected to decline in most scenarios of global change in the coming decades.

Data collection:

- InvaCost[113]
- Haubrock et al., 2021
- Brondízio et al., 2019
- Common bird index[114]
- Grassland butterfly index[115]

Level uncertainties: High

High level of uncertainty in modelling biodiversity-related risks and their potential impacts, due to several factors:

1. Incomplete data (see section on gaps and needs): the lack of comprenhensive data leads to gaps in understanding biodiversity and its role in providing ecosystem services, making it difficult to model accurately potential losses and impacts.
2. Ecosystem complexities, with numerous interdependencies and processes: this complexity can make challenging to fully understand the role of each species within an ecosystem and predict the effects of biodiversity loss on the ecosystem's overall function.
3. Non-linear responses: ecosystems often exhibit non-linear responses to changes, which makes it difficult to predicting when and how tipping points might be reached.
4. Technological/ methodological limitations, limiting the the ability of models to capture the complexity and dynamics of biodiversity-related risks.
5. Spatial and temporal variability: biodiversity and ecosystem processes vary across different geographic locations and time scales, which hinders consitent modelling of risks and impacts across regions.
6. Difficulty in economic valuation of nature and ecosystem services , as many benefits are indirect, long-term, or intangible. This leads to uncertainty in estimating economic impacts.
7. Biodiversity - climate change nexus: climate change is a major driver of biodiversity loss; uncertainties related to future climate scenarios and their effects on ecosystems would add another layer of uncertainty when it comes to modelling.
8. Socioeconomic factors: human activities, policy decisions, and economic developments might influence biodiversity outcomes. Unpredictable changes in these factors would also contribute to uncertainty.

Risk drivers and interactions

Air pollution

Risk drivers	• Environmental factors (weather/climatic conditions which determine the accumulation of air pollutants in the air and the formation of secondary pollution); • Urbanisation; • Land use change; • Technological developments (electrification of transport sector); • Agricultural practices (dietary habits)

113 InvaCost, Global database of economic costs of invasive alien species, https://invacost.fr/

114 European Environment Agency (EEA), Common bird index in Europe, https://ec.europa.eu/eurostat/databrowser/view/sdg_15_60/default/table?lang=en

115 European Environment Agency (EEA), Grassland butterfly index in Europe, https://ec.europa.eu/eurostat/databrowser/view/sdg_15_61/default/table?lang=en

Hazards triggering	• wildfires; volcanoes
Hazards triggered by	N/A
Cascading impacts	• Health effects; • Crop losses and reduced vegetation activity; • Economic losses;
Compound relationships	• Extreme climate events

Eutrophication

Risk drivers	• Urbanisation, poorly planned urban development (Urban wastewater contributing to excess nutrient loads); • Technological developments, developments in information technology and digitalisation (Industrial wastewater contributing to excess nutrient loads, Vehicle and industrial emissions driving atmospheric deposition of nitrogen oxides (NOx) and ammonia); • Agricultural practices (Agricultural runoff contributing to excess nutrient loads, contributing to excess nutrient loads); • Environmental degradation (Excess nutrient loads (nitrogen and phosphorus) from various sources, • Atmospheric deposition of nitrogen oxides (NOx) and ammonia into coastal waters); Aquaculture
Hazards triggering	N/A
Hazards triggered by	• Loss of biodiversity
Cascading impacts	• Environmental degradation (decreased water quality, depleted oxygen and algal blooms; • negative impacts on the marine organisms and ecosystems); • negative impacts on human health; • economic losses due to disruption of fisheries, aquaculture, tourism and recreational activities
Compound relationships	• Extreme weather events;

Marine chemical pollution

Risk drivers	N/A
Hazards triggering	• Industrial accidents; • transport accidents (maritime); • Natech; • armed conflicts; • sabotage;
Hazards triggered by	• environmental pollution; • loss of biodiversity
Cascading impacts	• Disruption of essential services (water supply) • Health impacts on the population; wildlife and ecosystems; • damage to habitats and infrastructure; • impacts on emergency responders; • Business interruption for fisheries and tourism;

Compound relationships	• floods and storm surge • storms

Marine macrolitter

Risk drivers	• Urbanisation, poorly planned urban development (rapid urbanisation contributing to waste mismanagement, poorly designed waste disposal and management systems); • Technological developments (advances in materials (e.g. plastic) have led to an increase of single-use plastics, packaging innovations, development of synthetic fibres) ; • Environmental factors (extreme weather events contributing to 'wash' land-based litter into the sea, transboundary transport); • Societal behaviours (consumer preferences for convenience (single-use plastic, packaging), littering, illegal dumping or disposal of litter); • Economic activities (global plastic production, ADLFG – abandoned, discarded or loss fishing gears)
Hazards triggering	• Direct disposals; • land-based runoffs; • extreme weather events.
Hazards triggered by	
Cascading impacts	• Entanglement and damage to habitats (additional damage to coastal infrastructure); • Ecosystem disruption; • Economic disruption; • Accumulation hotspots
Compound relationships	• Floods; • extreme weather events; • accidents; • chemical pollution.

Marine microlitter

Risk drivers	• Urbanisation, poorly planned urban development (rapid urbanisation contributing to waste mismanagement, poorly designed waste disposal and management systems); • Technological developments (advances in materials (e.g. plastic) have led to an increase of single-use plastics, packaging innovations, development of synthetic fibres, synthetic polymers added to cosmetic and personal care products, microplastics release from tyre wears) ; • Environmental factors (extreme weather events contributing to 'wash' land-based litter into the sea, transboundary transport); • Societal behaviours (consumer preferences for convenience (single-use plastic, packaging), littering, illegal dumping or disposal of litter); • Economic activities (global plastic production, ADLFG – abandoned, discarded or loss fishing gears, : pollution through paint erosion mainly in marine transports)
Hazards triggering	• Direct disposals; • land-based runoffs; • extreme weather events;
Hazards triggered by	N/A
Cascading impacts	• Entanglement and damage to habitats (additional damage to coastal infrastructure); Ecosystem disruption; Economic disruption; • Perpetuating the cycle of pollution and broadening its impact on both the environment and human society; Accumulation hotspots
Compound relationships	• Floods; • extreme weather events; • accidents

Biodiversity loss

Risk drivers	• Land/sea use change and its consequences, including an increasing fragmentation and thus decreasing connectivity of natural and semi-natural areas; • Direct exploitation (first driver of biodiversity decline for the marine realm) and its consequences, including land degradation; • Climate change associated with global warming and changes in weather patterns; • Pollution (e.g. plastics, nutrients) and its consequences, including eutrophication (i.e. the enrichment of water by nutrients resulting in degraded water quality); • Invasive alien species (plants, animals, pathogens and other organisms that are non-native to an ecosystem and which may cause economic or environmental harm or adversely affect human health); These are underpinned by indirect drivers (consumption/production habits driven by economy, demography, technology, governance).

Hazards triggering	In relation to direct drivers: • Loss/degradation of species' natural habitats • Decrease in the abundance of exploited species (e.g. fish, trees) • Threat to the ability of species to reproduce, feed, and ultimately survive under new climatic conditions • Decreased health and survival for species sensitive to pollution • Increase of inter-species competition between native and invasive species jeopardising native species persistence. In relation to indirect drivers, several examples for hazards are provided below: • Demographic changes: greater competition for space with depriorati-zation of conservation areas/ increased demand for natural resources due to population growth and settlement expansion, affecting sustainable land use; impact: overuse of ecosystem services and loss of critical ecosystems. • Economic factors: preference for short-term profit maximization in investments, prioritizing immediate financial gains over long-term environmental sustainability; impact: reduction of funding for conservation initiatives, leading to ecosystem decline. • Socio-cultural factors: changes in consumption behaviours like preference for fast fashion, increasing non-sustainable textile production; impact: ecosystem degradation due to chemical waste generation and pressure on water resources. • Institutional/ Governance factors: polic shifts affecting conservation efforts and environmental regulation; impact: reduced legal protection for ecosystem, increasing vulnerability to degradation
Hazards triggered by	• Degradation of ecosystems and decline / disruption in the supply of ecosystem services, including provisional services (e.g. provision of food, medicine and energy), regulation services (e.g. regulation of climate, air quality and water quality), and cultural services (e.g. spiritual, recreational and educational). • Misalignment between economic actors'/ an organization's strategy and the landscape in which it operates, i.e., current developments as governments/ organizations/ society undertake actions/ processes to protect nature or halt and reverse decline in the state of nature.

Cascading impacts	Major ecosystem disruptions, also leading to the effects highlighted below (illustrative examples, non- exhaustive): • Climate and environmental changes: i. acceleration of climate change due to reduced carbon sequestration, ii. increased occurrence of natural disasters due to weakened natural disaster resilience (deforestation, loss of coastal mangroves...) More specifically, physical and transition risks for the economy and financial sector: • Economic impact: i. Food shortages and loss of livelihoods as a consequence of decline in fisheries and agriculture, ii. supply chain disruptions • Financial impact: Biodiversity loss as a driver for traditional types of (financial) risks, from credit risk, reputational and operational risk including legal risk (for instance, increased litigation risks for state and non-state actors - e.g. companies, liable for biodiversity loss.), to market and liquidity risk. • Human health impacts: i. instability of global food systems, ii. increased risk of zoonotic diseases • Social&political instability: i. social tension and communities displacement, due to habitat degradation/ scarcity of natural resources; ii. increased inequality, as vulnerable communities are more exposed to environmental/ economic impacts of biodiversity loss.

Compound relationships	Climate-nature nexus is undoubtly an important feature to consider in this context (climate change as a driver of nature risk; nature degradation as a driver of climate risk, and climate change mitigation and adaptation as a potential driver of nature risk). Same would apply for biodiversity and health. Biodiversity loss and ecosystem disruption adversely affect various environmental dimensions, each with direct implications for human health. Some illustrative cases are shown below. 1. Cascading hazards: Biodiversity loss triggering multiple secondary hazards a. Mangrove degradation -> Coastal Erosion + Fisheries Collapse + Insurance Losses: Biodiversity loss from mangrove degradation triggering secondary hazards: (i) immediate ecological impacts such as loss of coastal protection from erosion and storm surge due to the loss of natural wave barriers, the collapse of nearshore habitats of fish/ crustraceans populations, or loss of carbon sequestration; (ii) cascading economic and financial impacts, such as increased physical risk with coastal communities and infrastructure becoming more vulnerable to flloding/ storm damage, with increasing repairing costs and insurance premiums/ uninsurability of coastal assets due to higher risk exposure; decline in fisheries leading to income loss and decreased food supply; tourism decline; financial system distress, incl. drops in real estate value, exposure of banks/ investors to coastal assets facing rising default rates; public finance burden, with governments diversing funds from other priorities. b. Decline in pollinator population ? loss in agricultural yields ? market price volatility + food insecurity 2. Concurrent hazards: biodiversity loss coinciding with other hazards a. Biodiversity loss + droughts+wildfires: biodiversity loss from monoculture farming and pesticide use + severe droughts and wildfires linked to climate change and land-use change, with (i) reduced ecosystem resilience worsening drought impacts, (ii) causing crop failures and lowering income from farming from direct damanges and lowe crop yield, which in turn (iii) supply chain disruptions increasing food prices, (iv) increases financial risk to investors and lenders. Also, (v) potential rural-to-urban migration due to livelihood stress. b. Overfishing + coral reef degradation in the same marine area 3. Other examples illustrating the impact of biodiversity loss in several environmental dimensions ultimately related to public health (Based on the WHO report Nature, Biodiversity and Health: An Overview of Interconnections WHO, 2021): a. Freshwater: degradation of ecosystems like wetlands and forests compromises water purification processes, leading to reduced access to clean drinking water and increased waterborne diseases. b. Air quality: loss of vegetation diminishes air filtration capabilities, resulting in higher concentrations of pollutants and allergens, which can exacerbate respiratory conditions such as asthma.

	c. Nutrition: reduced biodiversity in agriculture limits dietary variety and nutrient availability, increasing the risk of malnutrition and associated health issues. d. Infectious diseases: disrupted ecosystems alter the habitats of disease vectors, potentially increasing the spread of zoonotic diseases like malaria and Lyme disease. e. Mental health: limited access to natural environments due to ecosystem degradation can lead to increased stress, anxiety, and depression among populations. f. Climate regulation: destruction of carbon-sequestering ecosystems, such as forests and wetlands, accelerates climate change, leading to health risks from extreme weather events and heatwaves. g. Medicinal resources: biodiversity loss reduces the availability of natural compounds essential for developing medicines, hindering pharmaceutical advancements. h. Disaster risk reduction: degraded ecosystems lose their capacity to buffer against nat-ural disasters like floods and landslides, increasing human vulnerability and associat-ed health emergencies.

Gaps and needs

	Operational	Research	Policy
Air pollution	Inconsistent national and local inventories	Improving knowledge of health effects of air pollution; Harmonising air quality modelling; Developing a holistic approach to managing multiple air pollution risks; Challenge in integrating air quality models at different scale (from Global/European to city/street level); Challenge to have Integrated Assessment Models (that have a holistic view on environmental, economic and social impacts) working at different geographical scales; Challenge to integrate the different components of the IAMs	Inconsistent national and local inventories; Ensure coherence among different sectoral policies (i.e. on climate, air, transport, ...) and policy levels

Eutrophication	Improved monitoring and data availability of eutrophication indicators (e.g., nitrates, nitrites, phosphates, chlorophyll a, dissolved oxygen, macrophyte communities); Increased use of satellite data to improve monitoring of marine pollution;	Improved monitoring and data availability of eutrophication indicators (e.g., nitrates, nitrites, phosphates, chlorophyll a, dissolved oxygen, macrophyte communities); Increased use of satellite data to improve monitoring of marine pollution;	N/A
Marine chemical pollution	Data availability on cargo content of vessels; Data availability on HNS spills;	Study of long-term direct and indirect effects of spills on the environment, including for small, frequent spills, and for interaction between substances;	N/A
Marine macrolitter **Marine microlitter**	Improved monitoring technologies and data availability for marine macrolitter and microlitter;	Fate/transport mechanisms of marine litter and long-term ecological/economic impacts of marine macrolitter and microlitter, including adverse effects in combination with other pollutants; Development of more efficient removal/recycling solutions for marine macrolitter and microlitter;	Stronger international cooperation to address marine pollution; Improved policy enforcement to prevent and mitigate marine pollution; Increased public awareness campaigns to educate about the impacts of marine pollution;

Biodiversity loss	Data and Monitoring: Lack of comprehensive and high-quality data on biodiversity, including gaps in inventories, status, and variables. Integration into Decision-Making: Need for better integration of biodiversity risks into economic planning and decision-making. Public Awareness and Engagement: Need to raise awareness and engage stakeholders to mobilise actions towards biodiversity conservation and risk management. Funding and Resource Allocation: Insufficient financial resources for biodiversity conservation and restoration, including research, conservation efforts, and implementation of risk management strategies. Cross-Border Coordination: Need for enhanced transboundary collaboration in ecosystem management.	Biodiversity Variables: Poor representation of essential biodiversity variables, such as genetic composition and ecosystem function. Integrated Scenarios: Need to develop quantitative studies about future biodiversity scenarios accounting for multiple drivers of biodiversity loss and their interaction. Interdisciplinary Approaches: Need for a more interdisciplinary approach to understand and address the full scope of risks posed by biodiversity loss. Standardised Metrics and Indicators: Lack of standardised metrics for assessing biodiversity and nature-related risk, and consistent indicators across ecosystems and geographies. Understanding and Assessment of Diverse Biodiversity Values: Need for better understanding, quantification, and integrated monitoring of alternative values of biodiversity and ecosystem services.	Policy and Governance: Need for stronger regulatory frameworks for biodiversity conservation, including enforcement of existing laws and more effective implementation at national and local levels. Policy Coherence: Need for more policy coherence by integrating biodiversity-related risks across different policies. Enforcement and Implementation: Need for more effective implementation of existing laws and policies related to biodiversity conservation. International Cooperation: Need for enhanced international cooperation to address cross-border impacts of biodiversity-related risks. Institutional Capacity: Need for strengthened institutional capacity to support biodiversity conservation and management, including capacity building and training

Policy reference and adaptation/mitigation measures

Air pollution

Adaptation measures in place	CAMS Copernicus services[116] could be used to inform people on how to reduce exposure to air pollution (this is relevant for persons with specific health conditions).
Recommended adaptation measures	N/A
Mitigation measures in place	Mitigation measures to reduce air pollutant emissions through the use of abatement measures (e.g. at the stack of a plant or at the pipe of a vehicle, etc.), cleaner fuels, advanced and cleaner technologies (also with higher combustion efficiencies). Introduction of new policies to reduce emissions by source and country and air pollutant concentrations. Emission mitigation measures are applied both at national level, at source level (e.g. vehicle, plant, etc.) and at regional / local level (Air quality plans as foreseen in the AAQD). Covenant of Mayors and Climate Neutral Cities initiatives deal with GHG emission reductions, but can have impact also on air quality as side-effect.
Recommended mitigation measures	Decision Support Systems to help designing efficient and effective policies could be developed, so that local and national authorities are better informed.
Policy references	Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (recast) (European Parliament and Council, 2024f); NECD (2016/2284/EU) (European Parliament and Council, 2016); Industrial Emission Directive (2024/1785) (European Parliament and Council, 2024g); United Nations Economic Commission for Europe (UNECE) Air Convention and its pro-tocols (e.g. Gothenburg Protocol, etc., 1999) (UNECE, 1999); Fit for 55 package (European Commission, 2021e); Zero pollution Monitoring and Outlook report (last version published March 2025) (EEA & JRC, 2025); Forth Clean Air Outlook (European Commission, 2025c)

Eutrophication

Adaptation measures in place	Adaptation measures to Harmful Algal Blooms include • Monitoring programmes for the presence of phytoplankton toxins in shellfish, and establishing toxin limits in shellfish for human consumption • in aquaculture, towing the fish net pens away from the sites of intense HABs
Recommended adaptation measures	Increased monitoring, including the use of satellite data to complement in situ monitoring of eutrophication indicators and harmful algal blooms.

116 Copernicus Atmosphere Monitoring Service (CAMS), European Centre for Medium-Range Weather Forecasts (ECMWF), https://atmosphere.copernicus.eu/

Mitigation measures in place	Main categories of mitigation measures include measures to: • Limit nutrient loads from agriculture through input control • Limit nutrient loads from aquaculture through best management practices • Limit nutrient loads from urban and industrial sources, through management of urban waste water, storm water, industrial waste water, and shipping waste water. Example measures include the upgrade of urban waste water and industrial water treatment plants, development of sewerage systems. • Limit NOx and NH3 emissions into the atmosphere • Education, awareness and behaviour change measures (e.g., community outreach, reduction of food waste). • Surveillance measures such as the introduction of taxes, tax incentives, and compliance monitoring measures.
Recommended mitigation measures	Same as mitigation measures in place
Policy references	Marine Strategy Framework Directive (European Parliament and Council, 2008), Water Framework Directive (European Parliament and Council, 2000), Nitrates Directive (Eu-ropean Council, 1991), Revised Urban Wastewater Treatment Directive (European Par-liament and Council, 2024d), Industrial Emissions Directive (European Parliament and Council, 2024g)

Marine chemical pollution

Adaptation measures in place	Measures for prevention, preparedness and response to spills of mineral oil and HNS exist, such as satellite surveillance (in Europe, EMSA CleanSeaNet service, but also national satellite, aerial and ship surveillance); contingency plans; regular maintenance and inspection protocols for vessels, pipelines, storage facilities, and offshore platforms; phase-out of single-hulled vessels for transporting chemical cargo.
Recommended adaptation measures	Increase satellite surveillance and early alerts; create marine protected areas and spatially-explicit risk maps and manage ship traffic accordingly (e.g., reroute vessels carrying mineral oil or HNS away from zones with vulnerable ecosystems, fisheries or coastal communities); Improve safety standards and technology (e.g., automated navigation, pipeline technology, real-time monitoring of potential leaks); enforce stricter regulations (notably increase in regular inspections of shipping vessels, pipelines and storage facilities, increase penalties for infringements); Improve spill reporting, particularly for HNS.
Mitigation measures in place	Clean-up measures; bans on seafood consumption to decrease risk of contamination; regional and global cooperation (information sharing and joint exercises; Enhancing cross-border preparedness and response capacity, sharing resources and expertise during emergencies).

Recommended mitigation measures	Substance-specific containment and clean-up (using booms, skimmers, dispersants, and bioremediation techniques adapted to the chemical properties of the spill); efforts in reducing dependence on mineral oil and to phase out hazardous chemicals where safer alternatives exist; rehabilitation programs; ecosystem restoration projects; research and development (researching the behaviour of emerging hazardous chemicals in marine environments; interactions between substances; effects of minor, frequent spills on the environment, innovation in spill response technology, by developing advanced tools like autonomous underwater vehicles and nanotechnology).
Policy references	EU: Ship-Source Pollution Directive (European Parliament and Council, 2024e), Directive on Safety of Offshore Oil and Gas Operations (European Parliament and Council, 2013, as amended), Marine Strategy Framework Directive (European Parliament and Council, 2008), Environmental Crime Directive (European Parliament and Council, 2024h), Port reception facilities for the delivery of waste from ships (European Parlia-ment and Council, 2019c), Environmental Liability Directive (European Parliament and Council, 2004a). International: MARPOL (International Convention for the Prevention of Pollution from Ships) (International Maritime Organization, 2025)

Marine macrolitter

Adaptation measures in place	Environmentally Friendly Production Rules (e.g. extender producer responsibility); Financial Incentives for Environmentally Friendly Alternatives; Deposit - Return System
Recommended adaptation measures	Same as adaptation measures in place
Mitigation measures in place	Ban, banning the production of a product; Economic (dis)Incentives: tax, levy or fee to a non-environmentally friendly product or action. ; Education and awareness; Waste Management: Collection of Solid Waste, Wastewater Treatment, Management of Collected Waste, as they focus on the end-of-life management of the products; Removal actions;
Recommended mitigation measures	Same as mitigation measures in place

Policy references	Marine Strategy Framework Directive (European Parliament and Council, 2008); Waste Framework Directive (European Parliament and Council, 2008a); Packaging and packaging waste directive (European Parliament and Council, 1994); Urban Waste Water Directive (European Council, 1991); Strategic environmental assessment directive (European Parliament and Council, 2001); Port reception facilities for the delivery of waste from ships (European Parliament and Council, 2019c). The Plastic Bags Directive (European Parliament and Council, 2015); Single-Use Plastics Directive (European Parliament and Council, 2019d); Environmental Liability Directive (European Parliament and Council, 2004a) The End-of-Life Vehicles directive (European Parliament and Council, 2000a); Battery Directive (European Parliament and Council, 2006); Landfill Directive (European Council, 1999); Waste from Electrical and Electronic Equipment (European Parliament and Council, 2012); Directive 2007/60/EC on the assessment and management of flood risks (European Parliament and Council, 2007); MARPOL (International Maritime Organization, 2025); Global Treaty on Plastic Pollution (UNEP, in progress).

Marine microlitter

Adaptation measures in place	Environmentally Friendly Production Rules (e.g. extender producer responsibility); Financial Incentives for Environmentally Friendly Alternatives; Deposit - Return System;
Recommended adaptation measures	Same as adaptation measures in place
Mitigation measures in place	Ban, banning the production of a product; Environmentally Friendly Production Rules; Economic (dis)Incentives: tax, levy or fee to a non-environmentally friendly product or action; Financial Incentives for Environmentally Friendly Alternatives; Education and awareness; Waste Management: Collection of Solid Waste, Wastewater Treatment, Management of Collected Waste, as they focus on the end-of-life management of the products; Removal actions
Recommended mitigation measures	Same as mitigation measures in place

Policy references	Marine Strategy Framework Directive (European Parliament and Council, 2008) Water Framework Directive (European Parliament and Council, 2000) Packaging and packaging waste directive (European Parliament and Council, 1994); Urban Waste Water Directive (European Council, 1991); Strategic environmental assessment directive (European Parliament and Council, 2001); Port reception facilities for the delivery of waste from ships (European Parliament and Council, 2019c) The Plastic Bags Directive (European Parliament and Council, 2015); Single-Use Plastics Directive (European Parliament and Council, 2019d); Environmental Liability Directive (European Parliament and Council, 2004a) The End-of-Life Vehicles directive (European Parliament and Council, 2000a); Battery Directive (European Parliament and Council, 2006); Landfill Directive (European Council, 1999); Waste from Electrical and Electronic Equipment (European Parliament and Council, 2012); Directive 2007/60/EC on the assessment and management of flood risks (European Parliament and Council, 2007); MARPOL (International Maritime Organization, 2025); Global Treaty on Plastic Pollution (UNEP, in progress).

Biodiversity loss

Adaptation measures in place	In the case of adaptation to biodiversity loss, adaptation measures are imposed by the decline of biodiversity and the services it provides, and priority should be given to preventive/mitigation measures to avoid having to endure them. Adaptation is often reactive, costlier and less effective than proactive conservation. Preventing biodiversity loss before adaptation becomes crucial. Such imposed adaptation measures are mainly changes in what/how we consume and produce (food, energy, medicine) reflecting what ecosystems in their current state can still provide us with. Adaptation measures go beyond restoration and include actions to adjust to nature degradation and species decline, and can include: • Creation of ecological networks and connectivity planning, building networks of green spaces/ natural corridors that allow species migration/ adaptation to fragmented and changing. • Integration of biodiversity into urban planning, incorporating biodiversity-oriented design into buildings and infrastructures – pollinators habitats, wetland parks.. • Assisted migration or translocation of species • Promotion of agroecological practices and land use decisions that anticipate/ adjust to ecosystem degradation • Adaptive management of protected areas, updating conservation actions to shifting species status and ecosystem functions More specifically, and in terms of anticipating the disruption of pollination and the related ability of ecosystems to provide us with food, some strategies are starting to emerge to replace pollinators by drones or to grow food

	in laboratories. However, because these strategies are very demanding in terms of energy and material, they tend to amplify the primary causes of biodiversity loss (climate change, overexploitation of natural ecosystems and pollution), and are thus more maladaptation strategies than adaption strategies.
Recommended adaptation measures	Going forward, imposed adaptation measures will expand, representing mainly changes in what we will be able to consume and produce (food, energy, medicine) reflecting what ecosystems in their future state will still be able to provide us with.
Mitigation measures in place	Mitigation measures are widely used in the context of climate change, but can also be applied to biodiversity loss: as climate change is one driver of biodiversity loss, mitigating climate change would mitigate biodiversity loss. Furthermore, the climate-biodiversity nexus needs to be considered, where mitigation strategies are integrated across both dimensions. For biodiversity loss specifically, some mitigation measures are already in place, among which (non exhaustive list): • Implementation of EU and national biodiversity policies on the ground (e.g. establishment of protected areas, restoration of natural ecosystems, programs to protect endangered species, measures to reduce the drivers of biodiversity loss such as pollution, overexploitation, invasive alien species) • Changes in production and consumption behaviours so that they impact less biodiversity • Public awareness campaigns to highlight the importance of biodiversity and the services it provides • Mainstreaming biodiversity into all sectoral policies including agriculture, urban planning, and forestry
Recommended mitigation measures	Going forward, the existing mitigation measures should intensify: • Biodiversity policies on the ground should be better implemented, and biodiversity conservation issues should be actally considered in each sectoral policy to ensure the necessary cross-policy coherence for effective biodiversity conservation • Consumption and production behaviours should change more drastically to decrease their negative impacts on biodiversity • Public awareness campaigns to highlight the importance of biodiversity and the services it provides should expand. New measures could also help to adapt to the risk of biodiversity loss: • Horizon scanning on biodiversity conservation and foresight processes including participatory approaches to contribute actionable knowledge to support decision-making towards anticipatory governance to mitigate risk of biodiversity loss more efficiently • Economic investment in social and human capital for biodiversity (e.g. green jobs) may also provide win-win responses to biodiversity loss • Generalising the implementation of nature-based solutions would also provide win-win solutions to mitigate both climate change and biodiversity loss

Policy references	At EU level, the main EU policies in place to mitigate biodiversity loss and/or restore biodiversity are: • the Birds Directive (European Parliament and Council, 2009a); • the Habitats Directive (European Council, 1992); • the Marine Strategy Framework Directive (European Parliament and Council, 2008) • the Invasive Alien Species Regulation (European Parliament and Council, 2014); • the Biodiversity Strategy for 2030 (European Commission, 2020b); • the Nature Restoration Regulation (European Parliament and Council, 2024i); At global level, the main policy on biodiversity is the Kunming-Montreal Global Biodi-versity Framework of the Convention on Biodiversity (CBD, 2022).

Technological

Technological covers eight risks, which are Nuclear/Radiological risks, Disruption of essential services, Natech, Hydrogen fuel risks, Ammonia for Hydrogen Fuel Production and Transport, Renewable Energy material sourcing and processing, Battery energy including storage and Carbon Capture Storage and Distribution Systems.
Brief introduction is provided below for one of the risks covered in this category.

Disruption of essential services (physical risks)

Critical entities, as providers of essential services, play a crucial role in the maintenance of vital societal functions or economic activities in the internal market. The growing interconnections between critical entity infrastructure and sectors results in an increasingly cross-border and cross-sectoral network of service provision.

The disruption of essential services, such as those related to energy, transport, banking, finance, health, water, digital infrastructure, public administration, space and food sectors, is an emerging concern. Such disruptions can have far-reaching effects on the affected population and businesses, threatening public health, safety and security.

Moreover, essential services face numerous hazards, whether natural or man-made, accidental or intentional that can reduce the capacity, efficiency and lifespan of critical entities and supporting critical infrastructure. As these hazards and related risks propagate across interconnected systems, they can cause cascading disruptions to the provision of essential services, underscoring the need for enhanced resilience among critical entities and the infrastructures they operate.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Nuclear/Radiological risks	Yes	Yes	No	Yes
Disruption of essential services	Yes	Yes	Yes	Yes
Natech	Yes	Yes	Yes	Yes
Hydrogen fuel risks	Yes	Yes	Yes	Yes

Ammonia for Hydrogen Fuel Production and Transport	Yes	Yes	Yes	Yes
Renewable Energy material sourcing and processing	Yes	Yes	Yes	Yes
Battery energy including storage	No	Yes	Yes	Yes
Carbon Capture Storage and Distribution	Yes	Yes	Yes	No

Nuclear/radiological risk is characterised as a cross-border risk due to the potential for radioactive contam-ination to spread across national boundaries in the event of an incident. It is also considered an emerging risk, driven by advancements in novel nuclear technologies that bring new uncertainties and challenges mainly because it is difficult to assess and foresee and because recent conflict situations in areas with nu-clear or radiological installations call for new types of challenging events jeopardizing nuclear safety. Nuclear / radiological risks might also be classified as emerging because first-of-a-kind technologies related to nu-clear power—despite higher safety levels compared to the current state of the art—may bring novel risks characteristics not present in current technologies. While it is not classified as a climate-related risk, it falls under the category of high-impact, low-probability risks because nuclear incidents, though rare, can have catastrophic consequences.

Disruption of essential services is identified as a cross-border risk due to the interconnected nature of critical entities and service provision across national and sectoral boundaries. It is also classified as an emerging risk and a climate-related risk, as climate phenomena like extreme weather events can severely disrupt essential services. Lastly, it qualifies as a high-impact, low-probability risk because such disruptions, while infrequent, can have cascading effects that may have far-reaching effects on public health, safety, and economic stability.

Past **Natech** accidents have shown the potential for transboundary impacts, e.g. the Baia Mare mining accident in 2000 where rain and snowmelt led to the collapse of a tailings dam releasing about 100,000 m3 of cyanide-laced tailings waste. About 50–100 tonnes of cyanide entered several rivers (including the Tisza and Dan-ube) before reaching the Black Sea, affecting some 2000 km of the Danube's catchment area in Romania, Hungary and former Yugoslavia (Krausmann et al., 2021). UNECE with its Convention on the Transbound-ary Effects of Industrial Accidents (TEIA Convention) (UNECE, 2025) places great importance on Natech risks, i.e. via a chapter on Prevention of Natech accidents and adaptation to climate change in its "Road map for action to strengthen mine tailings safety within and beyond the UNECE region" (UNECE, 2022a), as well as its "Decision 2022/1 on strengthening Natech risk management in the UNECE region and be-yond" (UNECE, 2022b).

Natech is an emerging risk. Awareness of Natech risk has been growing over the past decade, including the realisation that climate change will increase the risk. Unfortunately, as a multi-hazard risk and the as-sociated complexities, Natech risk is difficult to analyse with traditional risk analysis approaches (Necci et al., 2022). Since climate change may affect the natural hazard trigger conditions (for hydro-meteorological hazards), making them more or less severe and frequent, depending on location, this must be considered in the Natech risk analysis to be able to prioritise Natech risk reduction measures. Also, the scenarios identified in the risk analysis are the basis for emergency plan preparation. Both the risk analy-sis and the emergency plans should be reviewed periodically and updated if necessary, in view of climate change (OECD/European Union, 2024).

Natech accidents can display HILP character which may be overlooked due to the complexity of Natech risk, leading to difficulties in analysing the risk appropriately and the screening out of low-probability events, and a disregard of natural hazards as accident triggers due to an Act-of-God mentality (Krausmann et al., 2021). The severity and geographic extent of such Natech accidents can be major, with impacts on the population, the natural and built environment, and the local, national or sometimes inter-national economy.

Hydrogen fuel, Ammonia for Hydrogen Fuel Production and Transport, Renewable Energy material sourcing and processing, Battery energy including storage and Carbon Capture Storage and Distribution, are considered a cross-border risks due to the interconnected nature of production, storage, and distribution infrastructure across regions. They are classified as emerging risk, reflecting the novel and evolving technologies associated with several of the technologies. Most of the items refer to critical infrastructure that is highly affected by extreme weather conditions. However small differences in annual temperature for example will not have an impact. Severe floods although can have a great impact on such infrastructure.

Consideration as HILP risk is very relative depending on the risk described. For the chemical/processing industry, there can be quite a few low-impact events but also high-impact, low-probability cases.

Loss, damages, and potential impacts

Nuclear/Radiological risks	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	Low		Low	

Nuclear/radiological risks can result in significant losses and damages across both economic and non-economic dimensions. Direct losses, such as those observed in the Fukushima disaster, are substantial, involving costs related to clean-up, infrastructure damage, and long-term economic disruption. There were also impacts on public health and environmental degradation. Indirect losses, such as reduced economic activity in affected regions, psychological trauma and loss of cultural heritage are also considerable (Fukushima example).

The **potential impacts** of nuclear/radiological risks are assessed as relatively low across all dimensions. Direct impacts are limited and considered low due to the rarity of such events. Similarly, indirect impacts, including broader disruptions to industries or supply chains and societal or psychological effects, are evaluated as low under normal circumstances.

Data collection: N/A

Level uncertainties: Medium

Disruption of essential services	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		High	
Potential impact (next 10 years)	High		High	

Data collection:

There are sectoral and hazard-specific databases at various scale. Relevant information can be retrieved on disruptions to essential services.

Level uncertainties: High

Uncertainties are high due to network complexities.

Natech	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low		Low	
Potential impact (next 10 years)	Medium		Medium	

Loss and damages: Due to the absence of (uniform) reporting obligations, there is no baseline for deter-mining Natech loss trends over the years (Krausmann et al., 2019). Based on past events especially outside the EU we know that direct Natech losses can be dramatic, as the release of flammable or explosive mate-rials due to natural hazard impact, and subsequent ignition or explosion can cause major physical dam-age, as well as lead to domino effects. During the Great East Japan Earthquake and Tsunami (GEJET) one LPG tank collapsed at a major refinery and the release ignited, in turn spreading to and destroying all 17 storage tanks at the site. The debris impact from the explosions caused several Natech accidents in neigh-bouring facilities and industries (Krausmann et al., 2013). In the EU, however, the losses from Natech acci-dents have so far been low. During the GEJET, many Natech accidents were triggered, damaging a high number of industrial facilities, with subsequent contagion into the global supply chain due to a loss of production capacity (Krausmann et al., 2021). Similarly, the contamination from the Fukushima NPP acci-dent led to enormous production and income reduction. This has not yet occurred in the EU.

Potential impacts: Due to climate change which affects hydro-meteorological Natech accident triggers, it is expected that Natech risk and related impacts will increase. However, this will be location specific, as the natural hazard triggers do not change equally everywhere. Increasing human development may also lead to more encroachment on natural hazard prone areas, thereby also increasing the Natech risk. The same reasoning as for direct impacts also holds for indirect impacts: with climate change the Natech risk will increase overall, and since Natech accidents are known also for their potential to cascade easily, also indirect impacts are expected to increase.

Data collection:

- eNATECH[117]

The only dedicated Natech accident database is eNATECH. Natech accidents can also be found in industrial accident databases. None of these databases provide Natech trends, as reporting is either voluntary or has consequence severity criteria for reporting. In a systematic analysis of pipeline Natech accidents in the US we found that the number of Natech accidents was slightly increasing over time. The study also found that while Natech accidents occur less frequently than accidents from other triggers, their consequences are more severe (Girgin et al., 2016).

Level uncertainties: High

With the many factors that act towards increasing Natech risk (climate change, industrialisation, urbanisation) it can be stated qualitatively that Natech risk will increase. A quantitative assessment is more difficult, due to uncertainties in:

1. data (especially lack of data on the industrial risk receptors)
2. models (need up to date natural-hazard models, new or refined equipment fragility models)
3. risk analysis methodologies (Natech risk analysis is complex due to its multi-hazard risk nature; there is a lack of consolidated Natech risk analysis methodologies)
4. climate change projections that affect the Natech trigger severity/frequency

117 NATECH: Natural hazard-triggered technological accidents database, European Commission Joint Research Centre, *https://enatech.jrc.ec.europa.eu/*

Hydrogen fuel risks	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		Medium	
Potential impact (next 10 years)	High		Medium	

Data collection:

- HIAD (Hydrogen Incident and Accident Database)[118];
- eMARS Major Accident Reporting System[119];
- ARIA (Analyse, Recherche et Information sur les Accidents)[120]

Level uncertainties: High

Ammonia for Hydrogen Fuel Production and Transport	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		Medium	
Potential impact (next 10 years)	High		High	

Data collection:

- HIAD;
- eMARS;
- ARIA;

Level uncertainties: Medium

Renewable Energy material sourcing and processing	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium		High	
Potential impact (next 10 years)	High		High	

The potential impacts of renewable energy material sourcing and processing are considered high. These include health risks from exposure to hazardous substances, environmental contamination from mining activities, supply chain vulnerabilities due to reliance on scarce resources, and challenges in waste management for end-of-life renewable components.
Data collection: No specific database available

Level uncertainties: High

118 Hydrogen Incident and Accident Database (HIAD), Joint Research Centre, European Commission, *https://minerva.jrc.ec.europa.eu/en/shorturl/capri/hiadpt*

119 eMARS Major Accident Reporting System, Major Accident Hazards Bureau, Joint Research Centre, European Commission, *https://emars.jrc.ec.europa.eu*

120 ARIA (Analyse, Recherche et Information sur les Accidents), French Ministry for Ecological Transition, *https://www.aria.developpement-durable.gouv.fr/*

Battery energy including storage	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium		High	
Potential impact (next 10 years)	High		High	

Data collection:

- eMARS;
- ARIA;
- BESS Failure Incident Database[121]

Level uncertainties: High

Carbon Capture Storage and Distribution	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High		Medium	
Potential impact (next 10 years)	High		Medium	

Data collection: No specific database available

Level uncertainties: Medium

Risk drivers and interactions

Nuclear/Radiological risks

Risk drivers	• Radionuclide materials stored / circulated in the nuclear / radiological facility • Technological developments (first-of-a-kind technologies); • Changing security landscape (armed conflict, geopolitical tension)
Hazards triggering	• Natural hazards (earthquake, floods, droughts); • Armed conflicts; • Fires • Internal hazards
Hazards triggered by	• Dose on the population • Soil contamination; • Disruption of essential services; • Exclusion zones
Cascading impacts	• * Power plant failure; • * Loss of electricity; • * Population relocation, • * Physiologic stress, • * Public health crisis, hospital operations.
Compound relationships	• earthquake, • droughts, • floods

Disruption of essential services

Risk drivers	• Climate change (increasing frequency and severity of extreme weather events and natural disasters, put strain on infrastructure and services); • Increased interdependence of essential services (a failure in one system can cascade to others, amplifying disruptions); • Globalisation and specialisation of supply chains (strained supply chains, lean or just-in-time inventory management); • Geopolitical uncertainty (changing geopolitical landscape affecting supply of critical resources, e.g., fuels, potential for conflicts over scarce resources); • Digitalization and technological advancements (new IT systems pose phisical risks to increasingly digitalised essential services); • Urbanisation and population density changes (rapid urbanisation and shifts in population density patterns can overwhelm existing infrastructure and services); • Economic and financial factors (insufficient investment in infrastructure maintenance and upgrades, undervaluation of climate risk in financial systems and investments).
Hazards triggering	• All hazards
Hazards triggered by	• Service-related failures; • physical damages; • supply disruption; • power outages;
Cascading impacts	• Human casualties and Diseases • Business losses • Physical, economic, social and environmental impacts with long lasting duration.
Compound relationships	• All hazards, one specific example is volcanoes, e.g. Eyjafjallajökul, 2010)[122]

121 EPRI, BESS Failure Incident Database, Electric Power Research Institute, *https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database*

122 Eyjafjallajökull volcano's 2010 eruption: The resulting plume caused an unprecedented disruption of air traffic and closure of airspace over large areas in Europe (Global Volcanism Network, 2010).

Natech

Risk drivers	• Industrialisation; • Urbanisation; • Lack of data and methodologies for Natech risk analysis; • Land-use changes (hard to keep risk receptors (hazardous industry, population) far enough apart from natural hazard areas, increasing the risk); • Economic constraints; ; • Climate change; • Risk awareness (lack of) and risk perception.
Hazards triggering	• All natural hazards (direct); • Loss of safety systems or utilities needed for accident prevention after natural hazard impact (indirect).
Hazards triggered by	• environmental pollution; • loss of biodiversity; • disruption of essential services; • fires; • chemical pollution; • explosions;
Cascading impacts	• Human health; • Environmental degradation; • Domino effects [EK30](fires and explosions can cause another accident in the same or neighbouring industrial sites, possibly leading to secondary hazardous material releases); • Business disruptions; • Economic disruption; • Supply chain disruptions
Compound relationships	• Multiple Natech accidents, triggered simultaneously. • Natural hazard (triggering hazard) unfolding simultaneously with Natech accident(s).

Hydrogen fuel risks

Risk drivers	• Physical characteristics (High reactivity, high flammability, large explosive range); • Technological factors (storage, transport conditions); • Technological and demographic developments (increase use leading to increased exposure);
Hazards triggering	• Extreme weather events; • Industrial failures (leaks/ruptures); • Electrolysis system failure;
Hazards triggered by	• Fires; • Explosions
Cascading impacts	• Injuries/fatalities (public, workers); • Severe property damage on and offsite; • Disruption of essential services (energy); • Supply chain disruptions; • Business interruption
Compound relationships	• Disruption of essential services (energy storage, renewable energy scaling, energy distribution networks)

Ammonia for Hydrogen Fuel Production and Transport

Risk drivers	• Physical characteristics (Toxicity, explosive under pressure, corrosive); • Infrastructure failure (aging facilities and facilities in emerging economies);
Hazards triggering	• Industrial failure (catastrophic equipment failure); • Extreme weather events; • Terrorism (e.g., attacks using explosives or hostile vehicles);
Hazards triggered by	• Industrial failure (leak/spills); • Explosions
Cascading impacts	• Injuries/fatalities (public/workers); • Severe property damage (including local businesses and residences); • Disruption of supply chain
Compound relationships	• Transportation hazards (Increase in exposure of many populations and businesses through distribution life cycle)

Renewable Energy material sourcing and processing

Risk drivers	N/A
Hazards triggering	• Mining hazards (poor practices); • Hazardous waste (handling practices);
Hazards triggered by	• Health hazards; • Soil pollution; • Air pollution; • Water contamination;
Cascading impacts	• Environmental degradation; • Economic disruption
Compound relationships	• Critical supply chain disruption; • Disruption of essential services;

Battery energy including storage

Risk drivers	• Physical characteristics (material degradation); • Technological factors (thermal runaway, electrical faults, mining practices); • Weak governance (lack of standardised protocols)
Hazards triggering	• Thermal runaway; • Electrical faults; • Unstable waste; • Mining hazards;
Hazards triggered by	• Fires; • Explosions; • Pollution
Cascading impacts	• Injury/fatalities (workers/public), • Severe property damage, • Business disruption, • Grid failure, • Cascading economic impacts, • Contamination of water bodies (mining failure)

Compound relationships	• Disruption of essential services (energy supply disruption); • Fires

Carbon Capture Storage and Distribution Systems

Risk drivers	• Technological factors (pipeline intergrity, gas leaks, geological storage factors)
Hazards triggering	• Industrial failure (pipeline and/or storage site failure)
Hazards triggered by	• CO2 pollution; • Environmental contamination
Cascading impacts	• Economic losses; • Disruption in the supply chain; • Reputational damage to CCS projects
Compound relationships	• Disruption to essential services (energy); • Financial risks

Gaps and needs

	Operational	Research	Policy
Nuclear / Radiological risks	Limited harmonised protocols for Emergency Planning and Response (EP&R).	Gaps in fast and accurate prediction and modelling of nuclear reactor phenomena after core melting. Unavailability of reliable nuclear risk maps.	Lack of harmonised policies for nuclear emergency preparedness and response.
Disruption of essential services	Knowledge fragmentation (limited expertise, shortcomings, missing common understanding, risk silos). Communication and cooperation (exchange of information, language barriers, public-private partnership) across sectors and countries Data availability and comparability (process transparency/sensitivity, consistency of results, interoperability, harmonisation of assessment methods)	Risk assessment/management complexity (fast-evolving risk landscape, non-linear causal/propagation chains, systemic, cascading, and compound risks across sectors and borders, supply chain risks, silos approach) System complexity (interdependencies, physical-cyber interface, asset and system specificities)	Risk ownership (degree and type of responsibility, competent jurisdiction) Risk prioritisation (building consensus among stakeholders)
Natech	Budget constraints Coordination of emergency planning for industry and for natural disasters Training of personnel	Data availability Model availability No consolidated analysis methodologies	Risk awareness Territorial approach to risk governance (including communication)
Hydrogen fuel risks	Outdated equipment, technical, and safety standards for hydrogen production, transmission, and distribution. Insufficient inspection and maintenance protocols for hydrogen infrastructure, including pipelines, grids, and networks. Limited training and competence of personnel involved in hydrogen production, transmission, and distribution. Inadequate emergency planning and response protocols for hydrogen-related incidents.	Need for research and development of new standards and protocols for hydrogen production, transmission, and distribution, including equipment standards, inspection and maintenance protocols, and emergency response planning. Requirement for updated consequence models and modelling software to assess the risks associated with new hydrogen fuel uses and conditions. Limited understanding of the risks and hazards associated with new hydrogen applications, requiring new research and modelling to inform decision-making and risk assessment. Need for studies on the effectiveness of different training and competence protocols for personnel involved in hydrogen production, transmission, and distribution. Requirement for research on the development of new decision criteria for evaluating hydrogen risks, including the consideration of new conditions and scenarios.	Need for updated national regulatory frameworks to accommodate new types of ownership, land-use planning, and increased population exposure to hydrogen infrastructure. Lack of harmonisation of standards and regulations across countries and industries, leading to inconsistencies and gaps in safety and environmental protection. Insufficient government oversight and enforcement of hydrogen-related regulations and standards.

Ammonia for Hydrogen Fuel Production and Transport	1. Inadequate material integrity assessments, leading to potential safety and environmental risks. 2. Insufficient management and maintenance of ports and pipeline infrastructure, both in the EU and in supplier countries, increasing the likelihood of accidents and spills. 3. Limited emergency response planning and preparedness, including inadequate trading and accident scenarios, hindering effective response to incidents.	1. Need for further research on advanced material integrity assessment techniques and technologies, including non-destructive testing and monitoring methods. 2. Limited understanding of the impacts of new conditions, such as climate change, on emergency planning and response, requiring more studies on scenario development and risk assessment. 3. Requirement for more research on the development of effective emergency response protocols and trading mechanisms, including the use of advanced technologies and data analytics, to support rapid and effective response to incidents. 4. Need for more studies on the integration of emergency planning and land-use planning decisions, including the development of risk-informed land-use planning frameworks and tools.	1. Lack of consistent and robust standards and regulations for material integrity, port and pipeline management, and emergency response in supplier countries. 2. Inadequate harmonisation of regulations and standards between the EU and supplier countries, leading to inconsistencies and gaps in safety and environmental protection. 3. Limited land-use planning decisions that take into account potential risks and hazards associated with ports and pipeline infrastructure.

Renewable Energy material sourcing and processing	1. Inadequate implementation of sustainable material sourcing standards, leading to potential environmental and social risks. 2. Limited visibility and transparency in supply chains, making it challenging to track and verify sustainable sourcing practices. 3. Insufficient training and capacity building for suppliers and stakeholders on sustainable material sourcing standards.	1. Need for further research on the environmental and social impacts of different material sourcing practices, including life cycle assessments and risk analyses. 2. Limited understanding of the effectiveness of different sustainable material sourcing standards and certification schemes, requiring more studies on their impact and efficacy. 3. Requirement for more research on the development of new and innovative sustainable materials and technologies, including biodegradable and recyclable materials, to support sustainable sourcing practices.	1. Lack of comprehensive and consistent policies and regulations for sustainable material sourcing, leading to inconsistent standards and practices. 2. Inadequate incentives and mechanisms for encouraging sustainable material sourcing practices, such as certification schemes and labelling programs. 3. Limited international cooperation and harmonisation of sustainable material sourcing standards, hindering global implementation and consistency.

Battery energy including storage	1. Inadequate safety standards for battery production, storage, and recycling/waste management, leading to potential accidents and environmental hazards. 2. Limited training for personnel in handling, storage, and waste management of batteries, increasing the risk of accidents and injuries. 3. Insufficient emergency response protocols in place, hindering effective response to battery-related accidents and incidents.	1. Need for further research on safe and sustainable battery production, storage, and recycling/waste management practices. 2. Limited understanding of the risks and consequences of battery accidents, requiring more studies on accident scenarios and emergency response protocols. 3. Requirement for more research on the development of new and improved safety standards, guidelines, and regulations for battery safety, including the use of new technologies and materials	1. Lack of comprehensive and updated regulations for battery safety, including production, storage, and recycling/waste management. 2. Inadequate guidelines for accident scenarios and emergency response, making it challenging to prepare for and respond to battery-related incidents. 3. Limited standards for training and certification of personnel handling batteries, leading to inconsistent levels of expertise and safety awareness.
Carbon Capture Storage and Distribution	1. Inadequate site monitoring, leading to potential safety and environmental risks. 2. Insufficient enforcement of pipeline standards, resulting in increased likelihood of accidents and spills.	1. Need for further research on advanced site monitoring technologies and techniques, such as real-time monitoring and predictive analytics. 2. Limited understanding of the effectiveness of different pipeline standards and materials, requiring more research on pipeline safety and durability. 3. Requirement for more studies on the environmental and social impacts of pipeline infrastructure, including the development of more sustainable and responsible practices.	1. Lack of robust and consistent pipeline standards, hindering the development of safe and reliable infrastructure. 2. Inadequate regulations and guidelines for site monitoring, making it challenging to ensure compliance and safety.

Policy reference and adaptation/mitigation measures

Nuclear/Radiological risks

Adaptation measures in place	N/A
Recommended adaptation measures	Harmonized methods and procedure for the Emergency Preparedness of radiological/nuclear accidents
Mitigation measures in place	Emergency Preparedness and Response activities (increase robustness of measurement station network, prognosis with atmospheric dispersion tools, and severe accident codes, methodologies for emergency planning zone definition, EUropean Radiological Data Exchange Platform (EURDEP), Diagnosis And Prognosis of Hazards in Nuclear Emergencies (DAPHNE))
Recommended mitigation measures	Harmonisation of Emergency Response methodologies (i.e., improving measurement stations arrangement, harmonisation of codes used for radioactivity dispersion and source term evaluations, general methodology for nuclear impact assessment)
Policy references	Basic Safety Standards (BSS, EU-2013) (European Parliament and Council, 2013, as amended); European Nuclear Safety Directive [EU-2014] (European Parliament and Council, 2014a)

Disruption of essential services

Adaptation measures in place	Climate-resilient infrastructure (less vulnerable), source diversification, redundancy, back-up systems, emergency response plans, early warning systems, real-time monitoring, communication channels, Hardening, strengthening and retrofitting infrastructures, automation and smart monitoring
Recommended adaptation measures	1. Invest in improving infrastructure resilience to withstand potential disruptions. 2. Develop and implement comprehensive emergency response plans to ensure a coordinated and timely response to disruptions. 3. Promote diversification and redundancy in supply chains and source systems. 4. Implement advanced systems to detect potential disruptions and provide timely alerts. 5. Strengthening cross-border policies, harmonising emergency planning (requirements and reporting of disruptions). 6. Fostering cooperation and information sharing among public and private sectors to address disruptions that may have transnational and cross-sectoral impacts. 7. Foster capacity building of workforce through training and exercise. System redundancies, backups and alternates (e.g., backup generators, hot and cold sites)
Mitigation measures in place	Critical infrastructure protection, Climate-resilient infrastructure (less exposed), smart technologies, advanced data analytics, business continuity plans, information sharing, enhancement of cyber-physical security interface, work force preparedness.

Recommended mitigation measures	1. Conduct regular risk assessment and risk management based on emerging threats and evolving technologies. 2. Provide resources for personnel responsible for maintaining essential services (i.e., ageing infrastructure) 3. Report potential threats or vulnerabilities including near-miss incidents. 4. Build a lessons learned culture for continuous improvement. 5. Collaborate with partners to share best practices, ensure data interoperability and coordinate efforts to prevent disruptions of essential services. 6. Continuously develop, monitor and update business continuity plans and contingency plans for essential services. 7. Decrease dependence on outsourcing and reliance on external service providers.
Policy references	Security Union Strategy (European Commission, 2020c) + Strategic Compass for Secu-rity and Defence (Council of the European Union, 2022) + Managing Climate Risks (Eu-ropean Commission, 2024d) + Disaster Resilience Goals (European Commission, 2023c) Recommendations on CI Stress testing (European Commission, 2024e) & CI Blueprint (European Commission, 2024f) CER Directive (European Parliament and Council, 2022e) + Delegated Act (European Commission, 2023f)+ sectoral legislations + transversal legislations White Paper for European Defence (European Commission & High Representative, 2025) European Internal Security Strategy – (European Commission, 2025d)

Natech

Adaptation measures in place	Resilience building, safety measures, risk analysis, training
Recommended adaptation measures	Preparedness for beyond-design basis events, risk monitoring, climate adaptation strategy, availability of natural hazard data, early warning
Mitigation measures in place	Consideration of natural hazards in design, construction and operation, risk analysis, emergency preparedness, lessons learning, legal framework
Recommended mitigation measures	Natural hazard design of safety-relevant infrastructure, land-use planning, inherent safety, retrofitting, reduction of GHG emissions
Policy references	Seveso Directive (European Parliament and Council, 2012b); Critical Entities Resilience Directive (European Parliament and Council, 2022e)

Hydrogen fuel risks

Adaptation measures in place	Current equipment/technical/safety standards and associated regulatory frameworks specific to hydrogen production, distribution, transport and storage systems.EU ATEX regulation (requirements for operating explosive atmospheres). However, these are not adequate for new operations envisioned for hydrogen fuel risk. Current hydrogen accident scenarios, models, and land-use planning criteria.
Recommended adaptation measures	Incorporation of safety into equipment design. Updating/creation of equipment/technical/safety standards and associated regulatory frameworks specific to new hydrogen production, distribution, transport and storage systems. Data gathering and research to update/create standards, regulations, guidelines, risk assessment models, risk evaluation criteria, updating of hydrogen accident scenarios to include new hydrogen uses and conditions, training and inspection protocols, and response etc. to ensure sufficient control of risks associated with hydrogen production, storage, distribution and transport.
Mitigation measures in place	Implementation of ATEX regulations, preventing ignition sources in explosive atmospheres, including equipment isolation. Equipment and operational areas are designed for mitigation with relevant pressure relief and ventilation capability, leak detection/mitigation (remote sensors, alarms, emergency shutdown systems, fire suppression systems, explosion resistant walls, rapid evacuation and first-response protocols, training and testing of response plans, mechanical integrity programmes (maintenance and inspection). Isolation of affected pipeline segments to stop hydrogen flow
Recommended mitigation measures	Design all new infrastructure with adequate mitigation enhancements all of which have been tested as fit for purpose. Ensure adequate explosion protection for plants involved in hydrogen fuel network. Implement land-use planning and risk evaluation criteria to keep populations away from risk. Mapping of distribution (plants and pipelines) networks. Enhance emergency planning response to new hydrogen accident scenarios. Updating of maintenance and inspection protocols. Investment in advanced containment equipment for hydrogen leaks Development of real-time incident mapping tools, International coordination on hydrogen release response protocols.
Policy references	EU Hydrogen Strategy (European Commission, 2020d); Seveso Directive 2012/18/EU (European Parliament and Council, 2012b)

Ammonia for Hydrogen Fuel Production and Transport

Adaptation measures in place	Storage and transport vessels and pipelines designed specifically for ammonia, with materials resistant to corrosion. Advanced leak detection systems and regular maintenance checks to ensure system integrity. Proper sealing techniques and fittings to prevent ammonia leakage during storage and transport. Robust safety standards and guidelines specific to ammonia production and storage systems. Storage tanks with appropriate materials and safety features to prevent leaks and withstand pressure variations. Mechanical integrity programmes (inspection and maintenance programmes). Ammonia detection systems and ensure proper ventilation in storage areas, and maintain equipment to prevent corrosion and mechanical failures.
Recommended adaptation measures	Recommended adaptation measures Technical standards for equipment design, international and national safety standards for ammonia handling and storage; Specialised training for personnel handling ammonia to ensure adherence to safety protocols; Emergency response plans and conduct drills to prepare for potential new ammonia accident scenarios
Mitigation measures in place	Current infrastructure are designed with mitigation capability, e.g., gas scrubbers to neutralize ammonia leaks, use of protective barriers to limit spread of toxic gas, emergency ventilation systems to disperse ammonia, pressure relief valves. There are inspection and maintenance programmes and internal and external emergency plans also in place on sites where ammonia is present. Diversion of pipeline and transportation routes to minimize public exposure
Recommended mitigation measures	Ensure infrastructure design incorporates proper mitigation measures, e.g., improved gas neutralization systems for large-scale ammonia spills, introduction of portable ammonia scrubbers for rapid deployment, enhanced training for first responders handling ammonia leaks and new accident scenarios. Also, capacity building, infrastructure and equipment investment, for chemical accident risk management in supplier countries in emergency economies will be needed.
Policy references	EU Hydrogen Strategy (European Commission, 2020d); Seveso Directive 2012/18/EU (European Parliament and Council, 2012b)

Renewable Energy material sourcing and processing

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	Tailings management; Containment of spills through physical barriers; Treatment of contaminated water or soil from extraction processes; Immediate reporting to regulatory authorities for coordinated response.

Recommended mitigation measures	Development of rapid-response units for contaminated site clean-up; Research into bio-remediation techniques for material spills; Introduction of stricter international coordination on mining incidents
Policy references	Critical Raw Materials Act (European Parliament and Council, 2024j)

Battery energy including storage

Adaptation measures in place	Monitoring systems to detect and address potential issues in real-time, Proper ventilation and cooling systems to prevent overheating and potential fires, environmentally sustainable extraction techniques, waste management systems for processing of rare metals such as nickel, lithium and cobalt, monitoring systems to detect instability, training of mining personnel, capacity building and equipment investment to enhance mining safety in emergency economies. Improved workforce training for managing battery waste, Upgrading of waste management facilities to monitor and mitigate potential incidents from unstable battery products
Recommended adaptation measures	International and national safety standards for energy storage systems; Energy storage systems with appropriate materials and safety features to prevent thermal runaway; Specialised training for personnel handling energy storage systems incidents; Emergency response plans and conduct drills to prepare for potential incidents; Design, monitoring and maintenance of containment; International collaboration to improve mining standards and regulations; Capacity building for risk management of mining sites in emergency economies
Mitigation measures in place	Development and deployment of enhanced fire suppression systems for battery fires, Building design for isolation and ventilation, Use of thermal barriers to prevent fire spread, Emergency removal of damaged batteries from the site, Tailings management, Containment of spills through physical barriers.
Recommended mitigation measures	Research into faster and more effective battery fire suppression techniques, Development of standardized protocols for battery removal in emergencies Training programs for workers and emergency responders on lithium-ion battery fires, Land-use planning criteria for battery storage sites, Introduction of stricter international coordination on mining incidents.
Policy references	Seveso Directive 2012/18/EU (European Parliament and Council, 2012b); Batteries regulation SWD/2023/57 (European Commission, 2023g).

Carbon Capture Storage and Distribution

Adaptation measures in place	Comprehensive geological surveys for storage sites Implementation of robust CO? containment systems monitoring systems to prevent leaks preventive maintenance and corrosion plans
Recommended adaptation measures	N/A

Mitigation measures in place	Rapid sealing of leaks in CO2 pipelines Activation of emergency venting systems to reduce pressure Coordination with local authorities to manage community exposure
Recommended mitigation measures	Research into advanced leak-sealing technologies Development of public risk communication strategies for CCS incidents
Policy references	IPCC Guidelines on CCS (IPCC, 2005; 2006)

Geopolitical and societal

Geopolitical and societal covers six risks, which are Armed conflicts, Hybrid threats, Illicit trafficking of nuclear/radiological material, Terrorism, Food insecurity in Europe and Unexpected Large-Scale Migration Flow.

Brief introduction is provided below for some of the risks covered in this category.

Hybrid Threats

Hybrid threats are a rising concern, posing complex challenges to democratic societies and their collective se-curity. These threats combine coercive and subversive tactics across multiple domains, aiming to destabilise democratic governments and undermine public trust in rule-of-law systems and institutions. Autocratic state and non-state actors use hybrid operations to achieve their hostile strategic objectives, utilizing a combina-tion of tactical tools such as disinformation, economic pressure, election interference, cyber-attacks, and other covert or overt actions.

In our interconnected societies, an attack in one domain can trigger cascading impacts across domains. These cascading effects, calculated or not by adversaries, can be weaponized in order to increase the impact of the original operation. Malicious actors exploit vulnerabilities, using diverse tools to achieve large-scale ef-fects across the society, the state and the economy. As hybrid threats are increasing, it is crucial to detect early signals in every domain, to develop capacities to determine the scope, nature and objective of the op-erations, to attribute it to the attacking adversary, even by addressing probability for responsibility, and im-plement measured retaliation, particularly in collective security frameworks, in order to better protect democ-racies. This underscores the need to build resilience and deterrence systems against these threats, anticipate future challenges and enhance the ability to withstand them.

Illicit trafficking of nuclear/radiological material

The illicit trafficking of nuclear and radiological material poses a significant threat to global security. This risk involves the unauthorized transfer, theft, or sale of nuclear and other radioactive materials. Materials falling out of regulatory control can cause serious harm to individuals and society, whether the transfer is intentional or accidental, and can cause widespread contamination and harm to humans and the environment.

Illicit trafficking of such materials requires particular attention. It can be carried out by various actors, including terrorist organizations, criminal networks, and rogue states, making it a highly complex and challenging issue to address. The consequences of illicit nuclear trafficking can be devastating, including harm to human health, environmental contamination, and economic disruption. A radiological dispersal device could cause widespread panic, displacement of people, and significant economic losses. Moreover, the use of nuclear or radiological material for malicious purposes could undermine trust in nuclear technologies and worsen nuclear proliferation concerns. Given the severity of these risks, it is essential to strengthen international cooperation and implement robust measures to prevent the

illicit trafficking of nuclear and radiological material. To achieve this, it is necessary to enhance border controls, improve nuclear security regulations, and increase public awareness about the dangers of nuclear and radiological terrorism.

Risks related to terrorism

Modern societies are increasingly vulnerable to terrorist attacks, which often target public spaces as well as critical infrastructure. While terrorism remains a low-probability event in many regions, its potential consequences can be devastating and long-lasting, including fatalities, economic disruption and severe psychological and social impacts. The primary attack methods employed by terrorists include:

1. Explosive attacks (e.g., vehicle-borne or person-borne improvised explosive devices)
2. Mass shootings (e.g., coordinated attacks on public spaces)
3. Vehicle-ramming attacks (e.g., targeting pedestrians in open areas)
4. Chemical, biological, or radiological attacks
5. Cyberattacks, targeting essential services and manipulating public perception

As terrorist threats evolve, attackers continually adapt their strategies based on existing security measures. In urban design, it is important to strike a balance between physical protective solutions, accessibility and the need to avoid fostering a climate of public fear. A comprehensive risk management approach includes prevention, mitigation, emergency preparedness and adaptation to emerging threats.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Armed conflicts	Yes	Yes	Yes	Yes
Hybrid threats	Yes	Yes	Yes	Yes
Illicit trafficking of nuclear/radiological material	Yes	Yes	No	Yes
Terrorism	Yes	Yes	No	Yes
Food insecurity in Europe	Yes	Yes	Yes	Yes
Unexpected Large Scale Migration Flow	Yes	Yes	No[123]	Yes

Conflict spillover refers to the possibility that an armed conflict spreads beyond its geographic boundaries to neighbouring countries, with the potential of destabilising an entire region. In addition to the spread of conflict itself, its impacts can also have regional spillover effects in terms of economic losses (including trade disruptions, loss of investment, and declining economic output), disruption of regional energy security and critical infrastructure (such as pipelines and refineries) and global food insecurity. Moreover, the sudden and massive influx of migrants and refugees fleeing a conflict zone can overwhelm host countries' resources and infrastructure, requiring a coordinated and sustained response from the international community to address any humanitarian crisis and prevent further destabilization of the affected region.

Armed conflict is considered an emerging risk, as in recent years, the global risk of armed conflict

123 Climate change impacts migration both in terms of patterns (e.g. internal or international migration) and volume. However, the link is not straightforward and context-specific, and climate change often interact with other migration drivers (e.g. conflict, economic conditions), so it is difficult to identify a general relationship. In general, migration tends to be internal or close to the origin country first (Duester, et al 2024 and Mcmahon, S. et al. 2021)

has increased significantly. While internal conflicts continue to be the most prevalent type of conflict worldwide, the primary concern for European states stems from the heightened risk of interstate conflict and its potential spillover effects. The Russian invasion of Ukraine marked a major shift, underscoring the threat of armed conflict in the region and the possibility of it extending to EU Member States. In this environment, European countries are also more exposed to hybrid threats, including cyber-attacks on critical infrastructure and national security systems, as well as sabotage efforts targeting essential sectors like energy and transportation. The military domain, included in hybrid threats, is also the object of more concern, regarding potential attacks below the threshold of formally declared warfare.

The link between climate change and conflict remains the subject of ongoing research. While there is general agreement that climate change is likely to increase overall conflict risk, its impacts so far appear to be relatively small compared to other risk factors, dependent on the social and political context and limited to certain types of conflicts, such as smaller, localized conflict over resources.

Empirical research has repeatedly shown that armed conflict follows a power-law distribution: while many conflicts are small-scale, a small subset of major conflicts result in extremely high impacts and numbers of fatalities. Therefore major armed conflicts fit the definition of a low-probability, high impact event.

Hybrid threats demonstrate mixed risk characteristics across all domains. They can manifest as cross-border risks, though some impacts may remain confined to domestic contexts. These threats are partially emerging, combining established and/or evolving threats. Their relation to climate risks is context-dependent, as certain scenarios may intersect, while others remain unrelated. Similarly, their classification as high-impact, low-probability risks varies, and there are both threats that are considered HILP, and others that are not.

The **illicit trafficking of nuclear and radiological material** is a cross-border risk due to its transnational nature, often involving unauthorised transfer, theft, or sale across borders. It is also an emerging risk as new methods and actors, including terrorist organisations and criminal networks, evolve to exploit vulnerabilities in nuclear security. While not climate-related, this risk is classified as high-impact, low-probability, as incidents are rare but could result in severe consequences such as harm to human health, environmental contamination, economic disruption, and widespread panic.
Terrorism is identified as a cross-border risk due to the ability of terrorist networks to operate across national and international boundaries, targeting public spaces as well as critical infrastructure. It is considered an emerging risk, as attackers continually adapt their strategies, employing methods such as explosive attacks, mass shootings, vehicle-ramming, and chemical, biological, radiological, or cyberattacks. While not classified as climate-related, terrorism is a high-impact, low-probability risk. Although rare in many regions, its consequences can be devastating, including fatalities, economic disruption, and severe psychological and social impacts.

Food insecurity in Europe is identified as a cross-border risk due to the interconnected nature of food supply chains and the potential for disruptions to affect multiple countries. It is considered an emerging risk, influenced by evolving factors such as geopolitical conflicts and economic instability. Food insecurity is also climate-related, as climate change is projected to negatively impact European food production, alongside non-climate factors like armed conflicts (e.g., the impacts of Russia's war on Ukraine). Finally, it is classified as a high-impact, low-probability risk, as significant disruptions, though rare, could have severe consequences for food availability and societal stability.

Migrants arriving at the EU external border can engage in onward movements in the EU, and large inflows can affect several EU countries at the same time. While the risk of migrant arrivals is not entirely new, it is a risk that is difficult to assess, as it does not fall under the traditional categories. Population movements become a hazard only when they are too large or too sudden to cope with, so it is difficult to isolate the hazard dimension from the coping capacity.
Moreover, migration movements are difficult to foresee (in terms of magnitude and timescale), especially when they represent sudden and significant changes from the past trend. They are dependent on highly uncertain events, linked to drivers of migration (e.g. the development of conflict) and intervening factors (e.g. border management practices of neighbouring countries). In other words, such a risk can arise from a situation that may not have been anticipated or prepared for, which creates new or unfamiliar conditions for the EU to respond to.

Climate change impacts migration both in terms of patterns (e.g. internal or international migration) and volume. However, the link is not straightforward and context-specific, and climate change often interact with other migration drivers (e.g. conflict, economic conditions), so it is difficult to identify a general relationship. In general, migration tends to be internal or close to the origin country first (Deuster, 2024; McMahon et al., 2021).

The arrival of migrants to the EU is a continuous and highly volatile phenomenon in terms of magnitude. The extent to which this volatility leads to the risk described here depends on how 'large and very large' is quantified as well as the level of preparedness of MS. In general, unexpected and very large numbers of migrant arrivals are high impact, medium probability events. The larger the arrivals in a relatively short period of time, the less likely the event is: for this to happen, there should be a significant triggering factor pushing people outside the country (e.g. the outbreak of a war) and enabling conditions for directing people towards the EU (e.g. geographical proximity, large diaspora, favourable conditions to cross the border). This for instance happened with the mass displacement from Ukraine after the Russian aggression (Barker et al., 2022).

Loss, damages, and potential impacts

Armed conflicts	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	High	High	Medium	Medium
Potential impact (next 10 years)	Medium		High	

Losses and damages: Armed conflicts can have major direct impacts on affected countries in terms of loss of life, destruction of infrastructure, environmental devastation. Lower-level impacts can include destruction and sabotage of critical infrastructure by adversarial states or non-state actors. In some cases of cross-border terrorism can also be considered a manifestation or impact of armed conflict. Indirect impacts of armed conflict can spread across many domains and are more difficult to assess, but the most obvious ones include economic losses caused by supply chain disruption and infrastructure destruction, impacts on regional energy security and global food security, and a sudden influx of refugees.

Potential impacts: Based on current conditions (war in Ukraine, escalating war in the Middle East, global rise of nationalism and authoritarianism, growing hostility on the international stage, declining influence of the United States and erosion of international rules and norms), we can expect the risk of armed conflict and associated losses and damages to remain relatively high in the next 10 years, much higher than in the first 2 decades of this century. Direct impacts include the loss of life and infrastructure destruction, which could affect multiple countries in and near Europe if conflicts continue to escalate and spread. We set the overall risk level to "medium", as armed conflict remains a rare event, with a relatively low baseline risk compared to other risks (e.g. from natural hazards), and does not affect all states equally. The risk of indirect losses is likely to remain high, as ongoing conflicts are likely to continue in the near future, with significant potential for escalation. As a result, most states in the European context are likely to experience some form of indirect impacts, including economic disruptions, energy insecurity and the risk of a sudden major influx of migrants.
Data collection:
The only systemic databases of armed conflict impacts focus on conflict fatalities. The two main sources of this information that are regularly updated are the Uppsala Conflict Database Program

(UCDP)[124] and the Armed Conflict Location and Event Dataset (ACLED)[125]. Data on other impacts (such as infrastructure destruction) is currently limited to specific conflicts (e.g. Ukraine, Gaza).

Level uncertainties: Medium

Hybrid threats	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low, medium, high		Low, medium, high	
Potential impact (next 10 years)	Low, medium, high		Low, medium, high	

For hybrid threats, it is impossible to categorise past losses or potential impacts as low, medium, or high due to the complexity of the issue, which spans 13 distinct domains (Giannopoulos et al., 2021). They are and can be low, medium or high, depending on the domain. Each domain varies in its nature, tools, and effects, making any uniform assessment across all domains impractical.

Data collection:

Many sources for data collection exists, as Hybrid threats involves 13 different domains.
Here are a few:

- ACLED
- European Commission Terrorism Events Database[126]
- Global Terrorism Database (GTD)[127] (until 2020)
- The Washington Institute Islamic State Interactive Map[128]
- UCDP
- Live Universal Awareness Map (Liveuamap)[129]
- International Crisis Group CrisisWatch Database[130]

Level uncertainties: High or low.

Uncertainty is high regarding future attacks, low regarding incoming attacks

Illicit trafficking of nuclear/radiological material	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Medium	Medium	Medium	Medium

124 Uppsala Conflict Data Program (UCDP), UCDP Conflict Encyclopedia, Uppsala University, *https://ucdp.uu.se/database*

125 Armed Conflict Location & Event Data Project (ACLED), ACLED Data Portal, *https://acleddata.com/*

126 European Commission, Terrorism Events Database, *https://counterterrorism.ec.europa.eu/databases/terrorism*

127 National Consortium for the Study of Terrorism and Responses to Terrorism (START), Global Terrorism Database, *https://www.start.umd.edu/gtd/*

128 The Washington Institute Islamic State Interactive Map, *https://www.washingtoninstitute.org/islamicstateinteractivemap/#home*

129 Live Universal Awareness Map (Liveuamap), *https://liveuamap.com/*

130 International Crisis Group, CrisisWatch Database, *https://www.crisisgroup.org/crisiswatch/database*

Data collection:

IAEA Illicit Trafficking Database[131]

Level uncertainties: Medium

Terrorism	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Medium	High	Medium	High
Potential impact (next 10 years)	Hig	High	High	High

The **potential impacts** of terrorism depends highly on the security situation. It is very difficult to assess, but given developments in the last months, the potential impacts, both direct and indirect, can be considered to be high.

Data collection:

There are databases (JRC but also commercial) on fatalities/injuries but not to other loss, e.g. European Commission Terrorism Events Database

Level uncertainties: N/A

Food insecurity in Europe	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Medium	Medium	Medium	High

When assessing the **loss & damage and potential impact,** a distinction of geographical areas should be done. The effects are different if we consider urban or rural areas, or if we consider Eastern countries.

The non-economic potential indirect impact could be high considering cascading impacts on health (malnutrition, stunting, disease vulnerability, impairment of brain function, mental health).

Data collection:

- Food supply and security dashboard[132]
- Global Report on Food Crises (European LMIC areas)[133]

Level uncertainties: Medium

We have low uncertainty on how production affects food security (e.g. with regards impacts on the market, on trade agreements,..), but measuring the coping capacity of countries and health systems is much more uncertain.

131 International Atomic Energy Agency (IAEA), Incident and Trafficking Database (ITDB), *https://www.iaea.org/resources/databases/itdb*

132 European Commission, Food supply and security dashboard, European Food Security Crisis preparedness and response Mechanism (EFSCM), *https://agridata.ec.europa.eu/extensions/DataPortal/food-supply-security.html*

133 Food Security Information Network (FSIN), Global Report on Food Crises 2024, *https://www.fsinplatform.org/report/global-report-food-crises-2024/*

Unexpected Larg-Scale Migration Flow	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	N/A	N/A	N/A	N/A
Potential impact (next 10 years)	N/A	N/A	N/A	N/A

Losses and damages: Due to the nature of the risk, it is challenging to provide a precise estimate of total losses (understood as economic costs). Additionally, while the costs associated with managing the risk, including reception on arrival, SAR operations, and asylum reception, are likely to be substantial, there is significant variation across Member States, as also the relative burden and emergency level linked to arrivals vary. Some examples from the recent past include:

- The Canary Islands have experienced increased arrivals in 2023 and 2024. In this framework, the local government has estimated the cost of reception and child protection services of unaccompanied minors alone at €157 million.[134]
- In the context of the Ukraine emergency, the EU Civil Protection Mechanism deployed significant resources, providing in-kind assistance and emergency operations valued at approximately €970 million for the 2022-2024 period both in the EU, Ukraine and other affected countries such as Moldova.[135]
- In April 2023 Italy declared a state of emergency due to increased sea arrivals. €5 Million were allocated to the Ministry of the Interior for emergency management.[136]
- In the context of Lithuania's declaration of a state of emergency linked to increased arrivals from Belarus in 2021, DG ECHO supported the Belarussian Red Cross with 200,000 EUR and allocated 500,000 to humanitarian assistance for migrants stranded on the Belarussian Border (DG ECHO, 2021).

It is challenging to classify non-economic impact as ""low, medium or high"" given that it is strictly linked to preparedness at the EU but also Member State Level. We can identify areas where non-economic impact could be most felt, and assign an impact level to each of them:

- Sea and land border-crossings (low): potential loss of human lives remain a significant risk during migrants journeys to reach the EU. According to the IOM Missing Migrants Project, since 2014 over 30,500 people have died on the Mediterranean routes, and 1,200 have lost their lives while moving irregularly within Europe.[137]

Additionally, non-economic impacts are likely to be first felt on services and operations related to:

- Arrival centres (medium), including specialised detention facilities or closed arrival centres. The impact of the risk could lead to over crowdedness, stress on medical screening services and delays in the identification of persons with special reception needs.
- Accommodation centres (medium): temporary exhaustion of housing capacity, overcrowdedness of accommodation centres stress on medical services and services for persons with special reception needs.
- General reception conditions (medium): strain on child protection services; increased demand of material reception conditions such as food, clothing, and other essential products (e.g, hygiene products, school items, medical supplies) as well as financial allowances or vouchers. Large inflows can also put a strain on family tracing capabilities, and case processing in general.

134 Gobiero de Canarias (7 October 2024), Canarias requiere al Estado el abono de más de 157 millones, *https://www3.gobiernodecanarias.org/noticias/canarias-requiere-al-estado-el-abono-de-mas-de-157-millones-por-la-atencion-de-menores-migrantes/*

135 European Commission (2024). Ukraine. *https://civil-protection-humanitarian-aid.ec.europa.eu/where/europe/ukraine_en*

136 Dipartimento della Protezione Civile (23 April 2023), Emergenza incremento flussi migranti: pubblicata l'ordinanza del Capo Dipartimento, *https://www.protezionecivile.gov.it/it/notizia/emergenza-incremento-flussi-migranti-pubblicata-lordinanza-del-capo-dipartimento/*

137 International Organization for Migration (IOM), Missing Migrants Project, *https://missingmigrants.iom.int/*

- Local infrastructure (low): strain on local housing, healthcare, and education services, potentially compromising the quality and availability of essential services.

Indirect non-economic impacts can be identified in the following areas:

- Unaddressed education needs of migrant children and adults may lead to long-term integration challenges and social exclusion.
- Over crowdedness in arrival and accommodation centres, combined with limited capacity of medical services due to increased demand, could lead to the spread of diseases and health emergencies.
- Social tension may escalate in local communities, fuelled by misinformation and disinformation, which can translate into anti-migrant sentiment, potentially straining community cohesion.
- At the political level, the influx of migrants may lead to heightened tensions, polarisation, and divisive rhetoric, which can undermine trust in institutions, further straining social cohesion.
- There is a risk of reputational damage to the EU, if it is perceived as being unable to manage migration effectively, leading to a loss of credibility and undermining the Union's perceived compromise to solidarity and human rights

Potential impacts: Taking into account recent evolution of key migration drivers (see section below on drivers), it could be expected that migration trends over the next 10 years will continue to be highly vola-tile, and difficult to predict in magnitude. As stated above, economic costs associated with past large in-flows vary significantly across Member States. We can draw some general considerations on this areas where costs could have a greater future impact, expanding on examples above:

- SAR operations, as large inflows of sea arrivals would require increased monitoring and assis-tance for vessels in distress-
- Emergency operations, including contingency planning, investments in emergency accommoda-tion, and enhanced medical screening capabilities and medical emergency services.
- Provision of material reception conditions, including increasing investments for accommodation infrastructure, procurement of services to fulfil basic needs (food, clothes, personal hygiene).
- Other reception services, especially those associated with inflows of persons with special reception needs (e.g., unaccompanied minors): increased capabilities and resources for child protection ser-vices, increased investments in education services.

For non-economic potential impacts:

- Sea and land border-crossings (low): the loss of human lives may increase with increasingly higher numbers of migrants attempting to cross the Mediterranean, or potential shifts towards more dangerous routes, or increased instrumentalisation of migration.
- Long-term impact on arrival and accommodation centres, and reception conditions (medium): this will largely depend on preparedness and contingency planning in place, but inflows of an unex-pectedly high magnitude could exacerbate over-crowdedness, homelessness, and the strain on health and specialised services. Provision of reception conditions and standards as set out in the Reception Conditions Directive may prove challenging, and Member States may encounter difficul-ties in ensuring education, health care, as well as ensuring effective access to the labour market.
- Local infrastructure (low): increased demand for private accommodation may lead to disruptions in the housing market, local services (particularly health and education) may face challenges in addressing an increased demand.

In terms of indirect impacts:

- Long-term integration challenges (medium), which could exacerbate social exclusion of migrants within the EU, and enhance social tension and anti-migrant sentiment.
- Political instability (medium): unaddressed integration challenges, combined with unexpected inflows could contribute to the rise of extremist parties which further enhance polarisation and

divi-sive rhetoric, potentially destabilizing the EU's political landscape.

- Increased risks of instrumentalisation of migration (medium): in the absence of adequate prepar-edness, increased inflows of migrants could be exploited by external actors.
- At the same time, effective preparedness and migration management in the long-term could translate into positive indirect non-economic effects:
- Economic opportunities (medium): A well-managed influx of migrants could bring new skills, la-bour, and economic opportunities to regions experiencing demographic decline.
- Community resilience: The crisis could test the resilience of local communities, potentially lead-ing to increased community cohesion and social capital.

Data collection: N/A

Level uncertainties: Medium

The arrival of migrants to the EU is a continuous but highly volatile phenomenon in terms of magni-tude.

Risk drivers and interactions

Armed conflicts

Risk drivers	• Poverty and inequality; • Weak governance; Ideology; • Geopolitical developments; • Technological change; • Economic developments
Hazards triggering	N/A
Hazards triggered by	• Mass Displacement of People; • Food insecurity; • Disruption of Supply chains; • Disruption of essential services
Cascading impacts	• Civilian casualties; • Mass migration; • Food and energy insecurity; • Economic disruptions
Compound relationships	• Climatological and extreme weather events; • Communicable diseases and natural hazard-related disasters such as earth-quakes can all exacerbate the impacts of armed conflicts, in particular via their impact on large groups of refugees.

Hybrid threats

Risk drivers	• Weak governance; • Lack of political resolve; • Division of allies sapping collective security • Changing security environment; • Geopolitical developments impacting the threat landscape; • Technological developments and digitalisation
Hazards triggering	• Hostility of foreign state and/or non-state actors; • Cooperation between actors • Weaponisation of domestic threats • Exploitation of internal vulnerabilities
Hazards triggered by	• Coordinated attacks related to multiple domains: political, public ad-ministra-tion, legal, intelligence, diplomacy, military defence, infra-structure, economy, space, cyber, information, social/societal, culture
Cascading impacts	• Economic disruption; • Political changes; • Cultural influence; • Domestic violence • Foreign covert or overt domination • Loss of sovereignty • Division and transformation of collective security architecture
Compound relationships	• All hazards are in a multi-domain compound relationship in a context of hy-brid threats (Jungwirth et al., 2023).

Illicit trafficking of nuclear/radiological material

Risk drivers	• Changing security landscape; • Geopolitical developments; • Globalisation (globalisation and increased trade; • Ideology (terrorist organisations and extremist groups)
Hazards triggering	• Armed conflicts; • terrorism
Hazards triggered by	• CBRNE hazards
Cascading impacts	• Injury/fatalities (workers/public); • Psychological stress
Compound relationships	• CBRNE hazards

Terrorism

Risk drivers	• Geopolitical situation • Ideologies • Lack of security/ instability • Missing social inclusion
Hazards triggering	• Radicalisation • State induced actors
Hazards triggered by	• Security instability • Armed conflict
Cascading impacts	• Perception of insecurity in the society
Compound relationships	• Terrorist groups have tried in the past to coordinate attacks in several coun-tries, which might amplify the impact society even physical and cyber.

Food insecurity in Europe

Risk drivers	• Climate change; • Environmental degradation (unhealthy soils, biodiversity loss, deteri-oration of water resources); • Geopolitical developments; • Changing security landscape; • Economic factors (downturns, high input costs, price volatility, food inflation)
Hazards triggering	• Natural disasters (droughts, floods); • Armed Conflicts; • Biological hazards (pests, diseases)
Hazards triggered by	• Social unrest
Cascading impacts	• Healthcare overload (malnutrition and the vulnerability to disease); • social inequality, exclusion and social unrest (exacerbate poverty); • Institutional breakdown; • Negative impact on education; • Increase the vulnerability to adverse climate events; • Economic disruption (agriculture); • Land abandonment; • Economic disruption (market volatility, food affordability); • Migration and demographic change (strain on local administrations, healthcare systems); • Supply chain disruptions (feed and non-food items imported into Eu-ropean markets);
Compound relationships	• Extreme weather events and armed conflicts; • Climate change and nature degradation; • Pest and diseases combined with extreme weather events or armed conflicts; • Volcano, earthquakes (if hit regions with poor supply chain perfor-mance, ex-acerbating the damage to rural infrastructure, and water and air quality)

Unexpected Large – Scale Migration Flow

Risk drivers	Structural drivers of migration are: • demographic characteristics (e.g. younger people tend to more easily move), • economic and labour market conditions, • environmental factors, • human development factors (e.g. availability of healthcare, housing), • political and institutional characteristics (eg. stability, corruption), • security events (e.g. armed conflicts, human rights abuses), • cultural norms, • supranational and international developments (trade agreements, re-mittances) These however interact with each other and have varying effects in terms of magni-tude of migration and patterns of migration (e.g. regu-lar/irregular movements) and in general have not immediate effects. The factors that more directly impact migration are triggering factors that accelerate or deteriorate these drivers (e.g. the outbreak of a full-scale war) and intervening factors (e.g. geographical proximity, availability of migration channels - being regular, e.g. visa or visa exemption, or irregu-lar, e.g. smug-gling services, border management practices of countries neighbouring the EU, and links in the origin countries, e.g. presence of diaspora), (Rosinska A., 2024).
Hazards triggering	• Significant security events, • Major economic shock. In addition, enabling factors such as geographical proximity, the pres-ence of social connections/ or a diaspora in the destination countries and the availability of migra-tion channels can contribute.
Hazards triggered by	N/A
Cascading impacts	N/A
Compound relationships	Overcrowdedness combined with fires in reception camps, as was the case in the Moi-ra fires of 2020[138]

138 In 2020, fires broke out Greece's largest reception centre, an overcrowded facility on the island of Lesbos, leaving nearly 13,000 people without shelter. See: Moria migrants: Fire destroys Greek camp leaving 13,000 without shelter, *https://www.bbc.com/news/world-europe-54082201*.

Gaps and needs

	Operational	Research	Policy
Armed conflicts	While near-real-time data on conflict fatalities is available through sources such as UCDP and ACLED, there is a lack of comprehensive data on other conflict-related impacts, like infrastructure destruction, currently does not exist. There is also a lack of near-real-time data on interstate disputes and tensions that could escalate into larger conflicts.	Existing conflict monitoring and forecasting models are not well-suited to capture inter-state conflict risks or sudden escalations in violence in previously stable areas.	There is a need to better integrate quantitative data, models and scientific evidence into decision-making in conflict prevention and resolution.
Hybrid threats	Improving understanding, early detection, determination, attribution, retaliation and counter-narrative measures Enhancing awareness on the challenge represented by hybrid threats Increasing the capacities to address hybrid threats Developing common strategies and capacities to attribute, deter, defend and respond	Threat assessment/ management complexity (cognition, fast-evolving threat landscape, non-linear causal chains, disruptions, combinations, data and pattern analytics, empirical studies, silos approach) (Democratic) System complexity (interconnections, weaknesses, cascading effects) Adversarial state and non-state actors (ideologies, offensive doctrines, strategies, capacities, capabilities, alliances, operational cooperation)	Reinforcing European and extra-European co-operation and communication Developing anticipation, understanding of resilience requirements and deterrence strategies Strengthening EU governance systems and integrated response capacities Developping retaliation systems and good practices Enhancing EU capacities to collect and share intelligence
Illicit trafficking of nuclear/radiological material	N/A	N/A	N/A
Terrorism	N/A	N/A	N/A
Food insecurity in Europe	N/A	N/A	N/A

Unexpected Large-Scale Migration Flow	1. Challenges and fragmentation in the systems collecting and analysing data and information on migration and on asylum, reception and border capacity of the MS which can limit the understanding of migration trends and patterns. 2. An improved use of data to inform policies could help develop more effective responses.	1. Need for further research on the root causes of irregular migration and the factors influencing return migration. 2. Limited understanding of the social, economic, and political factors that contribute to migration decisions, requiring more research on migration dynamics. 3. Requirement for more studies on the effectiveness of different migration policies and programs, including those related to reception capacity, vulnerability screening, and return migration.	1. Scarce data on reception capacity and occupation, making it challenging to manage migration flows. 2. Insufficient data on vulnerability screening, hindering the identification and support of vulnerable migrants. 3. Limited data on irregular migration and return, making it difficult to develop effective policies and programs.

Policy reference and adaptation/mitigation measures

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	EU Conflict Early Warning System[139], European External Action Service (EEAS) Mediation and Diplomatic Support[140], Instrument Contributing to Stability and Peace (IcSP)[141], European Peace Facility (EPF)[142], Permanent Structured Cooperation (PESCO)[143], European Defence Facility[144]

139 Factsheet EU Conflict EWS: https://www.eeas.europa.eu/sites/default/files/documents/Factsheet%20-%20EWS.pdf

140 Information about the EU Global Strategy to combine security, development and diplomatic actions in support of common peace and prosperity objectives: https://www.eeas.europa.eu/eeas/conflict-prevention-peace-building-and-mediation_en

141 The Instrument contributing to Stability and Peace (IcSP) is the EU's main instrument supporting security initiatives and peace-building activities in partner countries

142 The European Peace Facility (EPF) is an instrument aimed at enhancing the EU's ability to prevent conflicts, build and preserve peace and strengthen international security and stability

143 PESCO is a treaty-based framework for the 26 participating Member States to jointly plan, develop, and invest in collaborative capability development and to enhance the operational readiness and contribution of armed forces

144 Defence Equity Facility aims to support venture capital and private equity funds that are investing in European companies developing innovative defence technologies with a 'dual-use' potential.

Recommended mitigation measures	N/A
Policy references	Policy references on conflict prevention: JSWD: Updated toolset for EU Conflict Analysis and Conflict Early Warning (European Commission & EEAS, 2023); European Union Global Strategy (European Union, 2016); Instrument Contributing to Stability and Peace (IcSP) (European Parliament and Council, 2014b). Policy references on preparedness / response / resolution: Common Security and Defence Policy (CSDP) (2016) (European Union, 2016a); European Peace Facility[145]; Strategic Compass for Security and Defence (Council of the European Union, 2022); Civil Protection Mechanism (European Parliament and Council, 2013, as amended); European Defence Fund (2021)[146]

Hybrid threats

Adaptation measures in place	Many adaptation in the 13 domains. At the strategic level, more exercises, trainings, adaptations in different EU MS.
Recommended adaptation measures	Reinforcement of detection, determination, attribution and retaliation. Reinforcement of awareness, anticipation, adaptation and preparedness regarding a worsening security environment, including high impact events.
Mitigation measures in place	More coordination at the EU level, more communication to the societies (civic space) and private sector (services space) about the rising risks and behaviours to adopt, more deterrence means (deterrence by denial and deterrence by punishment) and clar-ity about EU and EU MS boundaries.
Recommended mitigation measures	More attribution of hybrid attacks, more democratic responses as retaliation to in-crease deterrence on future attacks, reinforcement of resilience means, including in the defence domain.
Policy references	Security Union Strategy (European Commission, 2020c); Strategic Compass for Securi-ty and Defence (Council of the European Union, 2022); Safer Together – Strengthening Europe's Civilian and Military Preparedness and Readiness (Niinistö, 2024); White Pa-per for European Defence – Readiness 2030 (European Commission & High Repre-sentative, 2025); ProtectEU: a European Internal Security Strategy (European Commis-sion, 2025d)

Illicit trafficking of nuclear/radiological material

Adaptation measures in place	N/A
Recommended adaptation measures	Harmonized methods for deterrence, detection and response
Mitigation measures in place	Detection architecture at EU Borders and within countries
Recommended mitigation measures	Harmonised concept of operation of detection and response, Rapid information shar-ing mechanisms among EU member states

145 The European Peace Facility (EPF) is an instrument aimed at enhancing the EU's ability to prevent conflicts, build and preserve peace and strengthen international security and stability

146 The EDF is the Commission's instrument to support Research and Development in defence.

Policy references	Action Plan to enhance preparedness against chemical, biological, radiological and nuclear security risks (European Commission, 2017c)

Terrorism

Adaptation measures in place	Intelligence, Police cooperation, capacity sharing e.g. on mitigation and protection measures
Recommended adaptation measures	N/A
Mitigation measures in place	Understand root causes, work against radicalisation, security measures, protection
Recommended mitigation measures	Anticipate: Identifying vulnerabilities and building capacity to anticipate threats; Prevent radicalisation by providing opportunities for young people at risk and support-ing the rehabilitation of radicalised prisoners; Protect by promoting security by design and reducing vulnerabilities to protect cities and people; Respond: Police cooperation and information exchange;
Policy references	Counterterrorism agenda COM(2020) 795 (European Commission, 2020e); Security union strategy (European Commission, 2020c)

Food insecurity in Europe

Adaptation measures in place	Common Agriculture Policy (European Commission, 2025e); Common Fisheries Policy (European Parliament and Council, 2013c)
Recommended adaptation measures	• Integrated approaches, e.g. Agroecology • Food Systems transformation (production, food environment, consumption and waste) • Behavioural actions: reduce the consumption of animal-based products and reduce food waste. • Increase resilience of agricultural systems including crop diversification, sus-tainable agricultural practices, water management, soil health, biotech solu-tions for agriculture • Digitalisation uptake: precision farming, access to services • Promote precision agriculture and breeding programmes for resilient crop va-rieties (more tolerant to extreme weather and more resistant to diseases).
Mitigation measures in place	EFSCM RECOMMENDATIONS (European Commission, 2024g): Recommendations on ways to mitigate risks and vulnerabilities, including structural issues putting at risk food supply chains, from the European Food Security Crisis Preparedness and Re-sponse Mechanism (EFSCM), from 17 July 2024; Common Agriculture Policy (European Commission, 2025e); Common Fisheries Policy (European Parliament and Council, 2013c)
Recommended mitigation measures	• Food waste reduction: improve food storage and distribution. • Set-up emergency stocks • Promote healthy diets • Climate-resilient agricultural practices • Alternative protein sources • Strengthening agricultural insurance schemes • Simplification of procedures

Policy references	• COM(2021) 689 (European Commission, 2021f). Contingency plan for ensuring food supply and food security in times of crisis. • COM(2022)133 (European Commission, 2022c). Safeguarding food security and reinforcing the resilience of food systems • SWD(2023) Commission Staff Working Document (European Commission, 2023h) - Drivers of food security

Unexpected large-scale migration flow

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	• Migration Preparedness and Crisis Blueprint: Operational framework for moni-toring and anticipating migration flows and migration situations, building re-silience as well as organising a coordinated response to a migration crisis. It includes activities to develop capacities in the areas of situational awareness, early warning and forecasting migration flows. • Integrated Political Crisis Response Mechanism: the Council's crisis response mechanism; aimed to coordinate the political response to major cross sectoral and complex crises, including in the field of migration. • Asylum Reserve Pool foreseen in the European Union Agency for Asylum Regulation (EUAA) (European Parliament and Council, 2021b), which establish-es a mandatory pool of 500 Member State experts to be available in the case of disproportionate pressure. • Voluntary Solidarity Mechanism (currently in place): relocation of asylum seekers to pledging Member States for one year, primarily from Member States confronted with disembarkations (following search and rescue opera-tions). • Permanent solidarity framework (as of 2025-2026): in line with the Annual Migration Management Cycle, EU countries will be able to choose between dif-ferent forms of solidarity, including relocations, financial contributions and operational support when faced with migratory pressure or significant migra-tory situations. • European integrated border management: coordinated by the EU Border and Coast Guard Agency (Frontex), it includes cooperation among all relevant au-thorities and agencies involved in border security and trade facilitation to es-tablish effective, efficient and coordinated border management at the external EU borders. • Crisis and Force Majeure Regulation (European Parliament and Council, 2024k) (as of 2026): addresses situations of crisis (understood as mass arri-vals or instrumentalisation), and force majeure (abnormal and unforeseeable circumstances outside a Member State's control), and provides for deroga-tions and solidarity measures for Member States. • New Reception Conditions Directive (European Parliament and Council, 2024l) (as of 2026): obliges Member States to Develop contingency planning in case of disproportionate arrivals.

Recommended mitigation measures	• Enhance support for addressing root causes of migration, such as poverty, conflict, and environmental degradation. • Ensure reception contingency planning is adopted across Member States. • Provide targeted support to local communities hosting large numbers of mi-grants, including funding for infrastructure, services, and social cohesion initi-atives. • Develop communication strategies to address misinformation and promote public awareness about migration and asylum.
Policy references	The current EU asylum acquis, namely the (recast) Reception Conditions Directive (2013/33/EU) (European Parliament and Council, 2013d); The building blocks of the New Pact of Migration and Asylum, namely the 2024 Recep-tion Conditions Directive (2024/1346) (European Parliament and Council, 2024l), the Crisis and Force Majeure Regulation (2024/1359) (European Parliament and Council, 2024k) and the Asylum and Migration Management Regulation (2024/1351) (European Parliament and Council, 2024m)

Extra-terrestrial

Risks related to outer space

Our society is increasingly exposed to a number of risks related to outer space. Some of the risks are due to hazards of natural origin and are always there, while others are due to human activity.
The hazards of natural original are:

1. Solar storms
2. Major meteorite impact

The man-made hazards are:

1. Space debris
2. Kessler syndrome, where space debris grows exponentially, rendering important regions in space inaccessible for satellites
3. Uncontrolled reentry or launch accident
4. Attacks on satellites (or their functioning)
5. Attacks on space-related ground infrastructure
6. Technological overdependency and its weaponisation

All these hazards actually result in risks, because there is exposure and vulnerability of people and assets. Some of these hazards physically impact the Earth surface, such as meteorite impact or uncontrolled reentry; others act in space and affect satellites. In most cases they risk to compromise the space-based services (the services that are offered by satellites) on which society depends more and more: communica-tion, navigation and observation[147]. Some risks are low-probability – high-impact; these include e.g. major meteor impact and Kessler syndrome. Others will have a more limited or localised impact combined with higher probability, but all of them have a cross-border impact. Some risks are rising due to increased use and mis-use of space, while for others their impact is growing due to our increased dependency on space.

147 More comprehensively, the space-based services are: communication (including data and internet connectivity); positioning, navigation and timing (PNT), here collectively referred to as navigation; Earth observation, monitoring and surveillance, including meteorological and astronomical observation, here collectively referred to as observation; as well as the emerging in-orbit servicing. In addition, there are space operations such as space exploration, asteroid mining, and lunar and planetary missions.

Risk Characteristics

	Cross-border	Emerging	Climate scenarios	HILP
Damage from solar storms	Yes	No	No	No (Yes for extreme cases)
Major meteorite impact	Yes	No	Yes	Yes
Space debris	Yes	Yes	No	No
Kessler syndrome	Yes	Yes	No	Yes
Uncontrolled reentry or launch	Yes	Yes	No	No
Attacks on satellites	Yes	Yes	No	No
Attacks on space-related ground infrastructure	Yes	Yes	No	No
Technological overdependence	Yes	Yes	No	No

Damage from solar storms is a global risk where borders are irrelevant, as its effects can impact the entire planet. While the risk is not new or unexpected, growing dependency on electronics and space sys-tems has increased exposure, though awareness is also improving. It is not considered climate-related un-der EU policy definitions, as its link to climate is tied to long-term solar activity rather than Earth-based causes. Extreme solar storms are classified as high-impact, low-probability events, with rare occurrences like the Carrington event of 1859 demonstrating their potential severity.
Major meteorite impacts are cross-border risks, as smaller impacts may cause localized damage, while larger ones can have regional or global consequences. The risk itself is well known and not emerging, though recent developments in countermeasures are notable. It is partially climate-relat-ed, as climate change could affect the resilience of ecosystems to such events (e.g., floods or fires). Meteorite impacts are classic high-impact, low-probability risks; while microscopic impacts occur con-tinuously, large-scale events with global effects are extremely rare but catastrophic.
Space debris poses a cross-border risk because it affects satellites in orbit, making national borders irrel-evant. It has been recognized as an emerging issue for years and may now be approaching es-tablished status. However, it is not linked to climate change and is not generally considered a high-im-pact, low-probability risk.
Kessler Syndrome, which involves cascading collisions of space debris rendering orbits unusable, is a cross-border risk affecting satellites globally. It remains an emerging risk despite being recognized for several years. While it is not climate-related, it represents the high-impact, low-probability extreme of space debris risks.
Uncontrolled reentry or launch events are cross-border risks because they often involve multiple na-tions even if the physical event is localized. These incidents are considered emerging due to increas-ing space activity but are not linked to climate change or categorized as high-impact, low-probability risks.
Attacks on satellites occur in space beyond borders and involve multiple nations, making them cross-border risks. They are emerging threats tied to the rise of hybrid warfare tactics. While not climate-related, extreme scenarios like nuclear detonations in space could qualify as high-impact, low-probability events.
Attacks on space-related ground infrastructure are geographically local but still cross-border in na-ture because such facilities often serve multiple countries. These attacks are also emerging threats linked to hybrid warfare but are neither climate-related nor typically high-impact, low-probability risks.
Finally, **technological over-dependence** (for space-related technologies) is a cross-border risk tied to EU-wide concerns over technological sovereignty rather than linked to individual Member States. While stra-tegic autonomy and economic security remain ongoing issues, they are still considered emerging. This risk is not climate-related and does not fall into the high-impact, low-probability cat-egory.

Loss, damages, and potential impacts

Damage from solar storms	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	High	High	High	High

Losses and damages: There have been a few solar storms that caused significant damage, but over-all and on average damage is low. Solar storms pose a health risk to humans in space.
Potential impacts: A very strong solar storm is expected to cause major damage to satellites in space, and to many electric and electronic systems on the ground, such as power and communications grids, po-tentially over large areas. A very strong solar storm may also seriously endanger the health of astronauts, and airline pilots and passengers especially at northern latitudes. The impairment of space-based services and of the functioning of ground-based electric and electronic systems and networks will result in signifi-cant economic loss. The impairment of functions mentioned above will result in casualties, e.g. in transport (no traffic lights) and care (hospitals).

Data collection:

On hazard (not impact):

- Solar Flares[148]
- Space weather[149]

Level uncertainties: Medium

The uncertainty is when a very strong solar storm will take place, it could be in 1 year, 10 years, 100 years.

Major meteorite impact	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	High	High	High	High

Meteorites have not caused serious damage except a hole in a roof in recent history. However, a major meteorite strike would probably have dramatic consequences for all of society.

Data collection:

- Earth Impact Database[150]

On hazard (not impact):

- ESA NEO Coordination Centre[151]

Level uncertainties: Medium

148 NOAA National Centers for Environmental Information, "Solar Flares," NOAA/NGDC https://www.ngdc.noaa.gov/stp/solar/solarflares.html; NASA High-End Computing Portal, "Solar Flares," https://data.nas.nasa.gov/helio/portals/solarflares/

149 European Space Agency, Space Weather Portal: https://swe.ssa.esa.int/

150 Planetary and Space Science Centre, University of New Brunswick, "Earth Impact Database," http://www.passc.net/EarthImpactDatabase/New%20website_05-2018/Index.html

151 European Space Agency, "Near-Earth Object Coordination Centre," https://neo.ssa.esa.int/

A major meteorite approaching Earth would probably be detected well in advance, giving time for prepa-ration although maybe not much could be done to avoid it.

Space debris	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Medium	Medium	Medium	Medium

Losses and damages: Satellites have been damaged by space debris, e.g. the EU's Sentinel-1B. Fur-ther-more, loss of data has implied loss of economic gain that would have accrued from the data.
Potential impacts include damaged satellites, risk to life of astronauts, loss of some space-based ser-vices (communication, observation, navigation). Also, potential loss of life and loss of quality of life, due to reduced communication and navigation capabilities, and disruption of astronomical ob-servations.

Data collection:
On hazard (not impact):

- EU SST Database[152]
- UN Register of Objects Launched into Outer Space[153]
- ESA's Fragmentation Database[154]
- ESA's Database and Information System Characterising Objects in Space (DISCOS)[155]

Level uncertainties: Low
Space debris and its evolution are routinely tracked.

Kessler syndrome	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	N/A	N/A	N/A	N/A
Potential impact (next 10 years)	High	Medium	High	High

Losses and damages: It has never happened.

Potential impacts would include many damaged satellites, risk to life of astronauts (which are how-ever few), permanent loss of a large number of space-based services. Furthermore, loss of life and loss of quality of life, due to much reduced communication and navigation capabilities. Other poten-tial impacts are increased risk of geopolitical instability due to loss of defence capabilities for com-munication, obser-vation and navigation, and disruption of astronomical observations.

Data collection:
On hazard (not impact):

- EU SST Database[151]
- UN Register of Objects Launched into Outer Space[152]
- ESA's Fragmentation Database[153]

152 EU Space Surveillance and Tracking Partnership, "EU SST Service Portfolio," https://www.eusst.eu

153 United Nations Office for Outer Space Affairs, "Register of Objects Launched into Outer Space," https://www.unoosa.org/oosa/en/spaceobjectregister/index.html

154 European Space Agency, "Fragmentation Database," https://fragmentation.esoc.esa.int/home

155 European Space Agency, "Database and Information System Characterising Objects in Space (DISCOS)," https://discosweb.esoc.esa.int/

- ESA's Database and Information System Characterising Objects in Space (DISCOS)[154]

Level uncertainties: Medium
The actual risk of a Kessler syndrome is not easy to quantify.

Uncontrolled reentry or launch	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Low	Low	Low	Low

Losses and damages: There have been a few rocket bodies or satellite fragments falling to earth without much damage.
Potential impacts include collision with an airplane or impact on the ground, leading to material dam-age and loss of life. The responsible country would incur reputational damage.
Data collection:
On hazard (not impact):

- CORDS Reentry Database[156]
- EU SST Database[157]
- UN Register of Objects Launched into Outer Space[158]
- ESA's Fragmentation Database[159]
- ESA's Database and Information System Characterising Objects in Space (DISCOS)[160]

Level uncertainties: Low
Higher uncertainty would apply when considering uncontrolled reentries as cascade from a Kessler syn-drome.

Attacks on satellites	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Low	Medium	Medium	Low

Losses and damages: It is not clear if it already happened, being a deniable element of hybrid war-fare, but so far no major losses. The threat of attacks, driven by anti-satellite weapons testing and geopolitical tensions, has spurred expenditures to ward off the threat.
Potential impacts: A large number of satellites could be destroyed if a nuclear bomb is detonated in space. The functioning of a large number of satellites can be temporarily denied by electronic meas-ures (jamming or spoofing). Individual satellites can be temporarily or permanently put out of function with targeted attacks.
Note: an attack on a satellite can be from Earth or from another satellite. It can be kinetic, explosive, high-energy beam (laser, microwave, and particles), EMP, signal jamming or spoofing, or cyber. They can cause reversible or permanent damage. If a large number of satellites is attacked, it would lead to a problematic loss of space-based services (communication, navigation, observation). If specific satellites that are crucial to security or defence are attacked, it would lead to vulnerabilities in those areas. Especially an attack on a large number of satellites would create a war climate.

156 The Aerospace Corporation, "CORDS Reentry Database," https://aerospace.org/reentries

157 EU Space Surveillance and Tracking Partnership, "EU SST Service Portfolio," https://www.eusst.eu

158 United Nations Office for Outer Space Affairs, "Register of Objects Launched into Outer Space," https://www.unoosa.org/oosa/en/spaceobjectregister/index.html

159 European Space Agency, "Fragmentation Database," https://fragmentation.esoc.esa.int/home

160 European Space Agency, "Database and Information System Characterising Objects in Space (DISCOS)," https://discosweb.esoc.esa.int/

Data collection:
Only a handful of past attacks on record, no systemic data collection.

Level uncertainties: Medium
Uncertainty is related to uncertainty in geopolitical evolution.

Attacks on space-related ground infrastructure	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Low	Low	Low
Potential impact (next 10 years)	Low	Low	Medium	Medium

Losses and damages: Physical attacks have probably not happened, but cyber attacks are routine like for other critical infrastructure. Expenditures are allocated to cyber protection, and less to physical protection, in line with other critical infrastructures.
Potential impacts: Damage to an individual attacked site would be locally considerable, but low on the big scale of things. An attack on space-related infrastructure would probably involve no or few human casualties. An attack on a few crucial sites could severely hamper delivery of space-based services (com-munication, navigation, observation) over large areas. An attack with a big impact would create a war climate.
Data collection: N/A

Level uncertainties: Low
Several countries are already active in hybrid warfare. Cybercrime and ransomware are the order of the day.

Technological over-dependence	Direct		Indirect	
	Economic	Non-economic	Economic	Non-economic
Loss and damage (past 10 years)	Low	Medium	Low	Low
Potential impact (next 10 years)	Low	Low	Low	High

Losses and damages: The EU was dependent on Russian launchers, and after the invasion of Ukraine we could not launch all satellites we wanted. US launchers could partially compensate.
Potential impacts: The direct economic impact of overdependence results because EU-produced products and services are more expensive than imported ones. The indirect impact is the risk of weaponisation of critical dependencies: access to products and services may be shut off; products and services may be com-promised.

Data collection:
There are study results on products and services for which the EU is overdependent, but no completeness and no database.

Level uncertainties: Low
The EU is well aware of its technological overdependency in the space sector in general. However, exactly where many of the real bottlenecks and most critical points are is less well understood.

Risk drivers and interactions

Damage from solar storms

Risk drivers	• The primary risk driver is Technological developments, expressed through: • Increasing dependence of society on (ground-based) electric and electronic systems and networks; • Increasing use of space, increasing number of satellites; • Increasing dependence on space-based services.
Hazards triggering	N/A
Hazards triggered by	• Space debris; • Uncontrolled reentry
Cascading impacts	• disruption of essential services (communication, navigation, observation), • Disruption of critical entities (hospital, financial); • transport accidents (loss of navigation and control in airplanes, ships, cars, traffic lights); • societal breakdown (crime, looting)
Compound relationships	• Any other disaster or event that further affects the services already affected by solar storms (communication, navigation, electronic control systems).

Major meteorite impact

Risk drivers	N/A
Hazards triggering	N/A
Hazards triggered by	• Floods, • tsunami, • earthquakes, • fires
Cascading impacts	• Local destruction; • Dust in the high atmosphere, leading to less daylight and global cooling, with consequences on food production and quality of life.
Compound relationships	N/A

Space debris

Risk drivers	The primary risk drivers are Technological developments, Geopolitical instability, and Weak governance, expressed through: • Increasing number of satellites, under inadequate global control; • Increasing dependency on space-based services; • Increasing number of independent satellite operators and low-cost ones, who may not adhere to risk reduction standards; • Anti-satellite weapons tests and deployments.
Hazards triggering	• Solar storms
Hazards triggered by	• Uncontrolled reentry

Cascading impacts	• A Solar storm may render satellites uncontrollable, resulting in collisions, causing Space debris, which may result in Uncontrolled reentry.
Compound relationships	N/A

Kessler syndrome

Risk drivers	The primary risk drivers are Technological developments, Geopolitical instability, and Weak governance, expressed through: • Increasing number of satellites, under inadequate global control; • Increasing dependency on space-based services; • Increasing number of independent satellite operators and low-cost ones, who may not adhere to risk reduction standards; • Anti-satellite weapons tests and deployments
Hazards triggering	• Solar storms
Hazards triggered by	• Uncontrolled reentry
Cascading impacts	• See under Space debris above • Loss of commercial satellite communication capacity, primarily phone and in-ternet in the air, at sea and in remote areas. • Loss of space-based Earth surveillance and monitoring. • Loss of government control capabilities may trigger criminal or subversive ac-tions.
Compound relationships	• Any other disaster or event that disrupts terrestrial services that provide the same function as the space-based services (in the first place connectivity, ob-servation and surveillance)

Uncontrolled reentry or launch

Risk drivers	The primary risk drivers are Technological developments, Geopolitical instability, and Weak governance, expressed through: • Increasing number of satellites, under inadequate global control; • Increasing dependency on space-based services; • Increasing number of independent satellite operators and low-cost ones, who may not adhere to risk reduction standards; • Anti-satellite weapons tests and deployments
Hazards triggering	• Space debris • Kessler syndrome • Anti-satellite weapons deployments.
Hazards triggered by	N/A
Cascading impacts	N/A
Compound relationships	N/A

Attacks on satellites

Risk drivers	The primary risk drivers are Geopolitical instability, Technological developments, and Weak governance, expressed through: • Aggression by state actors including hybrid warfare; • Crime (ransomware); • High dependency on space-based services, which makes satellites high-value targets.
Hazards triggering	• Any disaster (if exploited by an adversary in the context of hybrid warfare to overwhelm government coping capacity).
Hazards triggered by	• Space debris; • Kessler syndrome; • Uncontrolled reentry
Cascading impacts	• internal and external security consequences; • loss of space-based services (communication, navigation, observation); • economic and societal impact; • create a war climate.
Compound relationships	N/A

Attacks on space-related ground infrastructures

Risk drivers	The primary risk drivers are Geopolitical instability, Technological developments, and Weak governance, expressed through: • Aggression by state actors including hybrid warfare; • Terrorism or activism; • Crime (ransomware); • High dependency on space-based services, resulting in high-value targets.
Hazards triggering	• Any disaster (if exploited by an adversary in the context of hybrid warfare to overwhelm government coping capacity).
Hazards triggered by	• Space debris • Kessler syndrome • Uncontrolled reentry
Cascading impacts	• space-based services (communication, navigation, observation) over large ar-eas with regional economic and societal impact. • create a war climate
Compound relationships	N/A

Technological over-dependence

Risk drivers	The primary risk drivers are Geopolitical instability and Technological develop-ments, expressed through: • Trade controls; • Resource scarcity (e.g. raw materials).
Hazards triggering	N/A
Hazards triggered by	N/A

Cascading impacts	• Limitations on access to space. • Limitations on access to space-based services. • Lack of trust in space-based services (if component integrity cannot be veri-fied). • Loss of critical space-based services, with all the same consequences as de-scribed with the above space-related risks.
Compound relationships	• Breakdown in global trade • Conflicts in source countries

Gaps and needs

	Operational	Research	Policy
Damage from solar storms	Cost-benefit analyses of countermeasures	Detailed vulnerability as-sessments	N/A
Major meteor-ite impact	N/A	Meteor impact model-ling	N/A
Space debris	N/A	Quantitative studies on collision risks between space objects	N/A
Kessler syn-drome	N/A	Quantitative studies on collision risks between space objects	N/A
Uncontrolled reentry or launch	N/A	N/A	N/A
Attacks on sat-el-lites	N/A	N/A	N/A
Attacks on space-relat-ed ground in-fra-structure	Cybersecurity	N/A	N/A
Technological over-dependence	N/A	Deepening of the on-go-ing assessments of technological depend-en-cies in the context of space.	N/A

Policy reference and adaptation/mitigation measures

Damage from solar storms

Adaptation measures in place	none, other than existing systems resilience against calamities in general
Recommended adaptation measures	Build up solar-storm-proof backup systems for essential services

Mitigation measures in place	Early solar storm warning by solar monitoring from earth and from dedicat-ed space-craft. Modelling and prediction of solar storm propagation and of effects on Earth
Recommended mitigation measures	Set up an operational warning system of impending solar storm risks to providers of essential services that are vulnerable to solar storms
Policy references	REG (EU) 2021/696 of 28.04.2021 establishing the Union Space Programme (European Parliament and Council, 2021c), Art. 3.1.d(ii) 'SWE sub-compo-nent', observational pa-rameters related to space weather events

Major meteorite impact

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	• Programs on planetary defence by NASA and ESA, to detect and deflect aster-oids that approach earth. • Space Surveillance &Tracking capabilities existing and being expanded.
Recommended mitigation measures	N/A
Policy references	• REG (EU) 2021/696 of 28.04.2021 establishing the Union Space Pro-gramme (European Parliament and Council, 2021c), Art. 3.1.d(iii) 'NEO sub-component', the risk monitoring of near-Earth objects approaching the Earth

Space debris

Adaptation measures in place	Physical protection and redundancy in some space-based systems and components.
Recommended adaptation measures	N/A
Mitigation measures in place	• Space Surveillance & Tracking efforts to monitor space objects and pre-dict impending collisions, on which basis satellites take evasive manoeu-vres. • International agreements between authorities and space operators for satellite end-of-life removal. • Space debris removal experiments, but today this can only remove the very limited subset of large space debris moving in certain orbits.
Recommended mitigation measures	• Research, development and implementation of self-protection measures for satellites. • Further strengthening of the international agreements between author-ities and space operators for sustainable use of outer space, and of the incentives for satellite operators.

Policy references	• REG (EU) 2021/696 of 28.04.2021 establishing the Union Space Programme (European Parliament and Council, 2021c), Art. 3.1.d(i) 'SST sub-component', a space surveillance and tracking system aiming to improve, operate and pro-vide data, information and services related to the surveillance and tracking of space objects that orbit the Earth. • JOIN(2022) of 15.2.2022 An EU Approach for Space Traffic Management (Eu-ropean Commission and High Representative, 2022)

Kessler syndrome

Adaptation measures in place	N/A
Recommended adaptation measures	Consider terrestrial backup systems for the case of widespread outage of space-based critical services.
Mitigation measures in place	• Space Surveillance & Tracking efforts to monitor space objects and predict impending collisions, on which basis satellites take evasive manoeuvres. • International agreements between authorities and space operators for satellite end-of-life removal. • Space debris removal experiments, but today this can only remove the very limited subset of large space debris moving in certain orbits.
Recommended mitigation measures	• Research, development and implementation of self-protection measures for satellites. • Further strengthening of the international agreements between authorities and space operators for sustainable use of outer space, and of the incentives for satellite operators.
Policy references	• REG (EU) 2021/696 of 28.04.2021 establishing the Union Space Programme (European Parliament and Council, 2021c), Art. 3.1.d(i) 'SST sub-component', a space surveillance and tracking system aiming to improve, operate and pro-vide data, information and services related to the surveillance and tracking of space objects that orbit the Earth • JOIN(2022) of 15.2.2022 An EU Approach for Space Traffic Management (Eu-ropean Commission and High Representative, 2022).

Uncontrolled reentry or launch

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	Space Traffic Management initiatives from US and at global and EU level.
Recommended mitigation measures	N/A
Policy references	• JOIN(2022) of 15.2.2022 An EU Approach for Space Traffic Management (Eu-ropean Commission and High Representative, 2022).

Attacks on satellites

Adaptation measures in place	Some level of redundancy of satellite platforms and services
Recommended adaptation measures	Ensure adequate redundancy of satellite platforms and services
Mitigation measures in place	• Space Surveillance & Tracking efforts to monitor space objects and assess hostile intent. • International agreements against hostile acts in space. • Cybersecurity measures. • Hardening of satellites against various forms of attacks (only in some military satellites).
Recommended mitigation measures	• Increasing cybersecurity to keep up with increasing threats. • More self-protection measures on important satellites (monitoring of local surroundings, physical and electronical/electromagnetic hardening).
Policy references	• JOIN(2023) 9 of 10.03.2023 European Union Space Strategy for Security and Defence (European Commission and High Representative, 2023). • Directive (EU) 2022/2557 of 14.12.2022 on the resilience of critical entities (European Parliament and Council, 2022e). • Directive (EU) 2022/2555 of 14.12.2022 on measures for a high common level of cybersecurity across the Union (European Parliament and Council, 2022a). • Regulation (EU) 2024/2847 of 23.10.2024 on horizontal cybersecurity re-quirements for products with digital elements (European Parliament and Council, 2024a). • Council Conclusions – EU priorities at the United Nations during the 75th, 76th, 77th, 78th, 79th United Nations General Assembly (13.07.2020, 12.07.2021, 18.07.2022, 10.07.2023, 24.06.2024). - 2020: "15. … Responsible behaviour in outer space and the prevention of an arms race in outer space will remain a specific focus" (Council of the European Union, 2020). - 2021: "19. The EU will continue to promote the preservation of a safe, secure and sustainable space environment and the peaceful use of outer space. In this context, we will pursue our work on the implemen-tation and further development of the guidelines for the long-term sustainability of outer space activities." "22. … Responsible behaviours and prevention of an arms race in outer space will remain a specific focus." (Council of the European Union, 2021a) - 2022: "10. … The "New Agenda" will require … reinforcing global gov-ernance for the peaceful, secure and sustainable use of outer space" "12. … The EU will … promote responsible behaviours and prevention of the militarisation of and an arms race in outer space." (Council of the European Union, 2022a) - 2023: "21. As part of the "Pact for the Future", a 'New Agenda for Peace' … should also reinforce global governance for the peaceful, secure and sustainable use of outer space, and aim to strengthen synergies amongst the various governance initiatives to reinforce space security." (Council of the European Union, 2023a) - 2024: "25. The EU underlines the importance of complying with exist-ing international law applicable to space, with the Outer Space Treaty at its core. The EU and its Member States support the universalisation of and full compliance with the 1967 Outer Space Treaty, and will

	promote the adoption of norms of responsible behaviour to prevent an arms race in outer space. The EU supports strengthening the UN Office for Outer Space Affairs and recognises the role of the Commit-tee on the Peaceful Uses of Outer Space as the principal UN body dealing with international cooperation in the peaceful uses of outer space." (Council of the European Union, 2024) - 2022: "10. … The "New Agenda" will require … reinforcing global gov-ernance for the peaceful, secure and sustainable use of outer space" "12. … The EU will … promote responsible behaviours and prevention of the militarisation of and an arms race in outer space." (Council of the European Union, 2022a) - 2023: "21. As part of the "Pact for the Future", a 'New Agenda for Peace' … should also reinforce global governance for the peaceful, secure and sustainable use of outer space, and aim to strengthen synergies amongst the various governance initiatives to reinforce space security." (Council of the European Union, 2023a) - 2024: "25. The EU underlines the importance of complying with exist-ing international law applicable to space, with the Outer Space Treaty at its core. The EU and its Member States support the universalisation of and full compliance with the 1967 Outer Space Treaty, and will promote the adoption of norms of responsible behaviour to prevent an arms race in outer space. The EU supports strengthening the UN Office for Outer Space Affairs and recognises the role of the Commit-tee on the Peaceful Uses of Outer Space as the principal UN body dealing with international cooperation in the peaceful uses of outer space." (Council of the European Union, 2024)

Attacks on space-related ground infrastructures

Adaptation measures in place	N/A
Recommended adaptation measures	Ensure adequate redundancy of ground-based facilities
Mitigation measures in place	EU-driven measures for critical entities protection
Recommended mitigation measures	More attention to self-protection (cyber, physical, electromagnetic)
Policy references	• JOIN(2023) 9 of 10.03.2023 European Union Space Strategy for Security and Defence (European Commission and High Representative, 2023). • Directive (EU) 2022/2557 of 14.12.2022 on the resilience of critical entities (European Parliament and Council, 2022e). • Directive (EU) 2022/2555 of 14.12.2022 on measures for a high common level of cybersecurity across the Union (European Parliament and Council, 2022a). • Regulation (EU) 2024/2847 of 23.10.2024 on horizontal cybersecurity re-quirements for products with digital elements (European Parliament and Council, 2024a).

Technological over-dependence

Adaptation measures in place	N/A
Recommended adaptation measures	N/A
Mitigation measures in place	• Ongoing assessments of technological dependencies in the context of space, e.g. the Observatory of Critical Technologies run by DG DEFIS and JRC. • Strengthening of critical technologies and component production, and related RD&I, in the EU. • Rebuilding EU launch capacity. • Efforts by the EU in international trade and diplomacy.
Recommended mitigation measures	Continuing and reinforcing the ongoing measures
Policy references	• COM(2021) 70 of 22.02.2021 Action Plan on synergies between civil, defence and space industries (European Commission, 2021g). • Regulation (EU) 2019/452 of 19.03.2019 establishing a framework for the screening of foreign direct investments into the Union (European Parliament and Council, 2019e), amended by Commission Delegated Regulations (EU) 2020/1298 of 13.07.2020 and (EU) 2021/2126 of 29.09.2021. • JOIN(2023) 20 of 20.06.2023 European Economic Security Strategy (European Commission and High Representative, 2023a). • REG (EU) 2023/1781 of 13.09.2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem (European Parliament and Council, 2023). • JOIN(2023) 9 of 10.03.2023 European Union Space Strategy for Security and Defence (European Commission and High Representative, 2023).

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