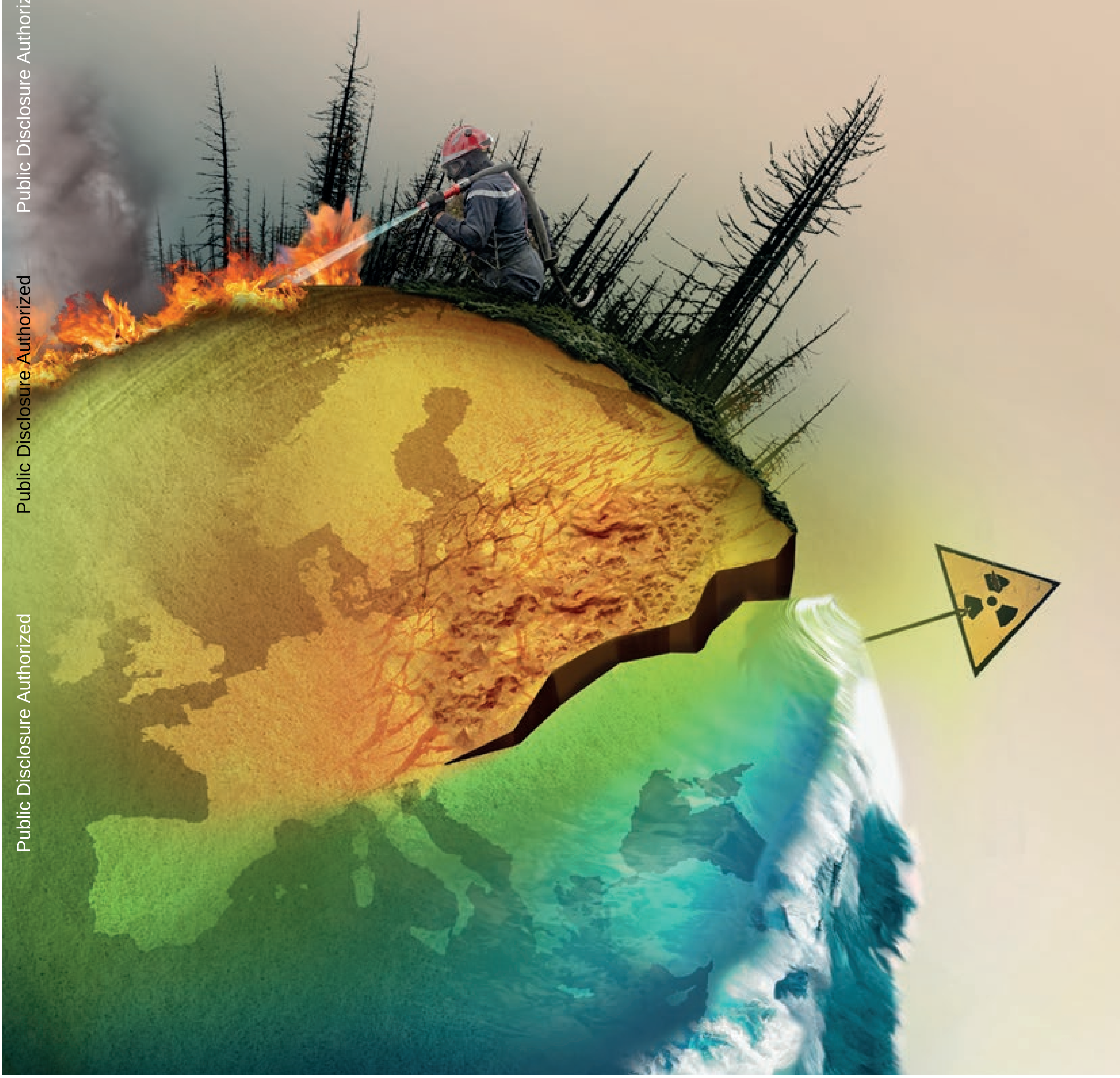
ECONOMICS FOR DISASTER PREVENTION AND PREPAREDNESS

# From Data to Decisions

## Tools for Making Smart Investments in Prevention and Preparedness in Europe



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## ABBREVIATIONS

| | |
|---|---|
| **AED** | Annual expected damage |
| **AAL** | Average annual loss |
| **AHP** | Analytical Hierarchy Process (prioritization tool) |
| **ANEPC** | National Civil Protection Authority |
| **ARA** | Albanian Road Authority |
| **SVSP** | Safe Village – Safe People (Aldeia Segura – Pessoas Seguras) |
| **BCA** | Benefit-cost analysis |
| **BCR** | Benefit-cost ratio |
| **CCA** | Climate change adaptation |
| **CCINIF** | Centre for the Coordination of National Information on Forest Fires |
| **CCM** | Climate change mitigation |
| **CDR** | Climate Resilience Dialogue (European Commission initiative) |
| **CEA** | Cost-effectiveness analysis |
| **CER** | Critical entity resilience |
| **CF** | Cohesion Fund (European Union) |
| **CFRAM** | Catchment Flood Risk Assessment and Management |
| **CIWIN** | Critical Infrastructure Warning Information Network |
| **CP** | Civil protection |
| **CRED** | Centre for Research on the Epidemiology of Disasters |
| **DG ECHO** | Directorate-General for European Civil Protection and Humanitarian Aid Operations (EC) |
| **DISS** | Database of Individual Seismogenic Sources |
| **DRG** | Disaster Resilience Goal (European Commission policy) |
| **DRM** | Disaster risk management |
| **DRR** | Disaster risk reduction |
| **EC** | European Commission |
| **EDO** | European Drought Observatory |
| **EDPP** | Economics for Disaster Prevention and Preparedness |
| **EM-DAT** | Emergency Events Database (CRED) |
| **EP&R** | Emergency Preparedness and Response |
| **ERDF** | European Regional Development Fund (European Union) |
| **ERR** | Economic rate of return |
| **ESG** | Environmental, social, and governance |
| **ESHM20** | 2020 European Seismic Hazard Model |
| **EU** | European Union |
| **EUCRA** | EU Climate Risk Assessment |

| | |
|---|---|
| **FEMA** | Federal Emergency Management Agency |
| **FRMP** | Flood risk management plan |
| **FSCP** | Fire Safety and Civil Protection (Romania) |
| **GDP** | Gross domestic product |
| **GEM** | Global Earthquake Model |
| **GFDRR** | Global Facility for Disaster Reduction and Recovery |
| **GI** | Green infrastructure |
| **GIS** | Geographic information system |
| **GUI** | Graphical user interface |
| **ICT** | Information and communication technology |
| **INFORM** | Index for Risk Management (European Commission initiative) |
| **IPCC** | Intergovernmental Panel on Climate Change (United Nations) |
| **IRR** | Internal rate of return |
| **ISGE** | National Energy Management Information System |
| **JRC** | Joint Research Centre (European Commission) |
| **KPI** | Key performance indicator |
| **LPI** | Largest patch index |
| **LSI** | Landscape shape index |
| **M&E** | Monitoring and evaluation |
| **MCA** | Multi-criteria analysis |
| **MFF** | Multi-Annual Financial Framework (European Union) |
| **MMI** | Modified Mercalli Intensity |
| **MS** | Member state |
| **NAIADE** | Novel Approach to Imprecise Assessment and Decision Environments |
| **NBS** | Nature-based solution |
| **NDMC** | National Disaster Management Centre |
| **NDRMP** | National Disaster Risk Management Plan |
| **NEXTA** | Network Explorer for Traffic Analysis |
| **NGEU** | NextGenerationEU |
| **NGO** | Nongovernmental organization |
| **NIS** | Network and information system |
| **NP** | Number of patches |
| **NPV** | Net present value |
| **NRRP** | National Recovery and Resilience Plan |
| **NTSC** | National Technical Standards for Construction |
| **ODI** | Overseas Development Institute |
| **OP** | Operational program |

| | |
|---|---|
| **PEKEPP** | Regional Civil Protection Centers |
| **PGA** | Peak ground acceleration |
| **PML** | Probable maximum loss |
| **PO2** | Policy Objective 2 |
| **PoM** | Program of measures |
| **PPP** | Public-private partnership |
| **PS** | Participating state |
| **R2R** | Ready2Respond (prioritization tool) |
| **RAMS** | Road asset management system |
| **RCP** | Representative concentration pathway |
| **RoI** | Return on investment |
| **RoR** | Rate of return |
| **RP10** | 1-in-10-year return period |
| **RP100** | 1-in-100-year return period |
| **RRF** | Resilience and Recovery Facility |
| **SDGs** | Sustainable Development Goals (United Nations) |
| **SFDRR** | Sendai Framework for Disaster Risk Reduction (United Nations) |
| **SMCE** | Social multi-criteria evaluation |
| **SRI** | Socially responsible investment |
| **SVSP** | Safe Village – Safe People (Aldeia Segura – Pessoas Seguras) |
| **TDR** | Triple Dividend of Resilience (prioritization tool) |
| **UCPM** | Union Civil Protection Mechanism (European Commission initiative) |
| **UHI** | Urban heat island |
| **UNDRR** | United Nations Office for Disaster Risk Reduction |
| **USGS** | United States Geological Survey |
| **UoM** | Unit of management |
| **VSL** | Value of statistical life |
| **WUI** | Wildland-urban interface |

*Note:* Throughout the report, currencies have been converted to euro values. If the original values were in other currencies, this is indicated in footnotes. The currency exchange rates used in this report come from the Eurostat database (Eurostat Database 2023). All dollar amounts are US dollars unless otherwise indicated.

EU countries' names and abbreviations used in the report:

| ABBREVIATION | COUNTRY | ABBREVIATION | COUNTRY | ABBREVIATION | COUNTRY |
|---|---|---|---|---|---|
| AT | Austria | FI | Finland | NL | Netherlands |
| BE | Belgium | FR | France | PL | Poland |
| BG | Bulgaria | HR | Croatia | PT | Portugal |
| CY | Cyprus | HU | Hungary | RO | Romania |
| CZ | Czech Republic | IE | Ireland | SE | Sweden |
| DE | Germany | IT | Italy | SI | Slovenia |
| DK | Denmark | LT | Lithuania | SK | Slovakia |
| EE | Estonia | LU | Luxembourg | | |
| EL | Greece | LV | Latvia | | |
| ES | Spain | MT | Malta | | |

## GLOSSARY

**Benefit-cost analysis (BCA) and ratio (BCR):** Process used to identify, measure, and analyze the benefits of a project, program, or decision versus the costs associated with it. BCR is the ratio used in BCA to summarize the relationship between overall relative benefits and costs of a project. A BCR higher than 1 means that the project's net benefits could be positive—that is, benefits are higher than costs.

**Climate change adaptation (CCA)** is defined as "the process of adjusting to live in a changing climate and making efforts to reduce the risk from the harmful impact of current or expected climate change and climate-induced hazards."[1]

**Climate change mitigation** is understood as "the effort to reduce climate change and decelerate global warming through the reduction of greenhouse gas emission into the atmosphere. Mitigation can be done by either reducing the sources of greenhouse gases of or improving the carbon sinks on Earth, which store and absorb greenhouse gases."[2]

**Critical sectors:** Per European Union (EU) regulations, critical entities are considered as providers of essential services, which "play an indispensable role in the maintenance of vital societal functions or economic activities in the internal market in an increasingly interdependent Union economy."[3] The EU regulation focuses on critical infrastructure such as assets, facilities, and equipment as well as networks, systems, or sectors necessary for the provision of an essential services. EU legislation refers to sectors such as energy, transport, banking, financial market infrastructure, health, drinking water, wastewater, digital infrastructure, public administration, space, and food. In this report, the term 'critical sector' refers to the civil protection and emergency response sector, including assets, such as fire and police stations, education and health care facilities (buildings), equipment, as well as roads and power lines. Critical sectors and categories of entities are not consistently recognized across all member states, and there is a degree of variability, although each member state should have in place a strategy for enhancing the resilience of critical entities, setting out respective objectives, policies, and measures.

1 IPCC (Intergovernmental Panel on Climate Change). 2012b. "Glossary of Terms." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,* edited by C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, et al., 555–564. A Special Report of Working Groups I and II of the IPCC. Cambridge University Press, Cambridge, UK, and New York, NY, US. Link.

2 EEA (European Environment Agency). 2023b. *What Is the Difference between Adaptation and Mitigation?* Link.

3 EU (European Union). 2022. *Directive 2022/2557/EU*. Link.

**Direct and indirect benefits/costs:** Benefits/costs either directly or indirectly associated with the impact of the project/program/decision. An example of a direct benefit is the prevention of asset losses or enhancement of environmental value due to a flood prevention measure while a direct cost is the cost of the flood prevention measure. An example of an indirect benefit is the prevention of productivity losses given the flood measure, while an indirect cost is the increase in prices in the area leading to displacement and loss of welfare/well-being of certain populations.

**Disaster risk management (DRM):** Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster DRM and risk transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development.[4]

**Disaster risk management investments:** Investments in risk identification (risk assessments and so on), risk reduction (prevention), early warning, emergency and response preparedness, public awareness, financial resilience (various instruments), and resilient recovery.

**Disaster risk reduction (DRR):** Aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.[5]

**Energy performance of a building:** The calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, among others, energy used for heating, cooling, ventilation, hot water, and lighting.

**Essential service:** A service which is crucial for the maintenance of vital societal functions, economic activities, public health and safety, or the environment.[6]

**Emergency service:** A service, recognized as such by the member state, that provides immediate and rapid assistance in situations where there is, in particular, a direct risk to life or limb, to individual or public health or safety, to private or public property, or to the environment, in accordance with national law.[7]

**Exposure:** The situation of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas.[8]

**Green infrastructure:** Sustainable, nature-based infrastructure that makes use of natural processes and ecosystem services for functional purposes, such as DRR. Such infrastructure usually yields risk reduction benefits and social and environmental effects.

**Green investment:** A broad term that is referred to at different levels, for example, investment in underlying technology and projects, to green companies and financial products that invest in those, or even to entire asset classes. It can be stand-alone or a subset of a broader investment theme or undertaken in the form of an investment overlay, for example, the integration of climate change or environmental, social, and governance (ESG) elements in the general investment approach or legal socially responsible investment (SRI) compliance.[9]

**Grey infrastructure:** Structural, human-engineered infrastructure for flood or other DRM, which includes both static and active elements and is usually built with materials like steel and concrete.

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4 World Bank and European Commission. 2021a. *Economics for Disaster Prevention and Preparedness: Financial Risk and Opportunities to Build Resilience in Europe - sInvesting in Disaster Risk Management.* Link. See also UCPM Knowledge Network - Disaster Prevention and Management. Link.

5 UNDRR (United Nations Office for Disaster Risk Reduction). 2017. *Build Back Better—In Recovery, Rehabilitation and Reconstruction.* Link.

6 EC (European Commission). 2022.

7 EU. 2018. *Directive 2018/1972/EU*. Link.; *Directive 2019/882/EU*. Link.

8 UNDRR 2017.

9 Inderst, G., Kaminker, Ch. and Stewart, F. 2012. *Defining and Measuring Green Investments: Implications for Institutional Investors' Asset Allocations*. OECD Working Papers on Finance, Insurance and Private Pensions, No.24, OECD Publishing. Link.

**Multi-criteria analysis (MCA):** A methodological approach and common tool used to evaluate and select among options or measures analyzing several criteria. It is a structured, yet flexible, framework allowing users to combine expert evaluations.

Nature-based solutions (NBSs): Solutions inspired by, supported by, or copied from nature and "simultaneously provide environmental, social and economic benefits and help to build resilience" by bringing "more and more diverse, nature and natural features and processes into cities, landscapes and seascapes."[10]

**Net present value (NPV):** Difference between the present value of monetary inflows and the present value of cash outflows over a period. NPV projects all future monetary inflows and outflows associated with a project/program/ decision, discount all these flows to the present day, and add them together. A positive NPV means that, after accounting for the time value of monetary flows, the project/program/decision could yield net benefits.

**Preparedness:** A state of readiness and capability of human and material means, structures, communities, and organizations enabling them to ensure an effective rapid response to a disaster obtained as a result of action taken in advance.[11]

**Prevention:** Any action aimed at reducing risks or mitigating adverse consequences of a disaster for people, the environment, and property, including cultural heritage.[12]

**Prioritization** is part of a broader decision-making process, which has several stages, including the development and use of a prioritization framework. Prioritization by public entities occurs at different governance levels focusing on policy and investments, location or type of assets, or type of interventions—multi-hazard, hazard specific, or structural/ nonstructural, infrastructure or social resilience related, and so on. Developing and using a prioritization framework requires decision-makers to consider various aspects and criteria and how to combine them given specific policy context, objectives, stakeholder context, funding, timelines, and so on. Analytical tools are available to guide decision-makers in deciding over specific elements and using criteria.

**Resilience:** The ability of a system, community, or society exposed to hazards to prevent, protect against, respond to, resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.[13]

**Sensitivity analysis:** Analysis that determines and showcases how results change when assumptions, parameters, or variables of an analysis are changed.

**Vulnerability:** The conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards.[14]

***Source:*** Unless otherwise indicated, World Bank and European Commission 2021a.

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10 World Bank/GFDRR. 2023. *Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers.* Link.
11 EU. 2021. *Decision 1313/2013/EU*.
12 EU 2021.
13 UNDRR 2017.
14 UNDRR 2017.

# Statement from the European Commission

In just a few short years, we have experienced a rising deluge of unprecedented and overlapping disasters.

Just few months after this Commission started its mandate, COVID-19 changed the world as we knew it: overwhelming our medical systems, isolating us from loved ones and closing borders and trade routes. Then just as we started to recover, the spectre of war returned to European soil with Russia's aggression against Ukraine – depriving an entire population of basic services and threatening the security and prosperity of European society. This all came on top of the biggest challenge of our age, the climate crisis, which is now manifesting itself in the daily lives of Europeans with record-breaking heatwaves, floods, wildfires, and droughts.

In the face of all this, the Union Civil Protection Mechanism has provided the operational backbone for Europe's collective emergency response, addressing the needs of populations affected by disease, war, and climate impacts both within the Union and beyond. Between 2020 and 2023, the annual average number of requests for assistance received by the Mechanism was 6 times higher than the annual average of the previous decade. As the Commissioner in charge of crisis management I am proud to say that, in spite of the shockwaves sent by these crises, EU solidarity has held strong.

With disasters and crises becoming simultaneously more frequent, intense and complex, and with increasing cross-sectorial and transboundary impacts, simply relying on response capacities is no longer enough to keep people safe. We must do more to strengthen our resilience. A year ago, we adopted the Union Disaster Resilience Goals to set Europe on a path towards enhanced disaster and crisis resilience through civil protection. These five goals, Anticipate, Prepare, Alert, Respond and Secure, must be pursued collectively to be effective. They all stem from the same imperative: to help Europe and its citizens anticipate and withstand the effects of future disasters and crises.

In little more than one year, we have made the Disaster Resilience Goals a reality. Our progress has been impressive. Together we developed a series of disaster scenarios to identify gaps in our collective prevention and preparedness for current and future risks. We mapped civic engagement and volunteer-based initiatives to promote citizens' risk awareness and preparedness, starting with wildfires. We strengthened and consolidated our EU-wide early warning systems into a single portal, doubled our aerial firefighting fleet, prepositioned firefighters in vulnerable regions, and are taking steps to identify our business continuity needs in order to find improvement.

Recent disasters have revealed that, to operationalise the Disaster Resilience Goals, urgent investments are needed at all levels, starting with critical sectors that provide emergency response services. The needs are huge and the pressure on the EU and government budgets is high; we therefore need to invest in a smart way, prioritising the investments with the highest resilience "dividends". But with so many simultaneous risks and often competing priorities, where should decision-makers invest to mitigate and manage such risks? A blueprint with tools and examples can help to make focused and smart investments. This is the reason why we partnered with the World Bank and leveraged their global experience to provide the evidence and the tools you will find in this report.

Investing in disaster resilience is not only good policy – it also makes economic sense. It is now demonstrated that prevention and preparedness investments deliver multiple benefits to our society, economy and environment which materialise whether a disaster happens or not. This means that while we improve our capacity to withstand the next disaster we can, at the same time, contribute to making our future greener and more sustainable. This study helps to fill the data and knowledge gaps so that governments can make decisions that maximize efficiency and effectiveness while also scaling up European resilience.

However, if we want to encourage investing in disaster resilience we need to pair strong evidence to close collaboration across different policy areas and administrative levels, promoting a culture of prevention and preparedness across all sections of our society. This study provides some of the information leaders need to take on these issues. At the European Commission we stand ready to support our Member States in protecting our citizens and ensuring a better and more resilient future.

***Janez Lenarčič***

Commissioner for Crisis Management,
European Commission

# Statement from the World Bank

We live in a time when crises have become normal. In Europe, the scale of loss and destruction from disaster events is staggering. Recent years recorded multiple concurrent major disasters—including floods, wildfires, heatwaves, and droughts. In 2023 alone, the hottest year on record, economic losses from disasters amounted to €77 billion across Europe.[15]

Europe is warming faster than any other continent in the world. Recent events indicate a disturbing trend — ongoing global warming driving increasingly intense climate extremes. Projections suggest that economic losses from climate-related events in the EU could soar to €175 billion per year in a 3°C warming scenario.[16]

Globally—and in Europe—disasters have far-reaching effects, with the vulnerable suffering the most.[17]Disasters not only have a direct impact on physical assets and infrastructure, but also increase poverty and exacerbate inequality over the long term. When mechanisms to prevent, prepare, respond, and recover from disasters are missing or inadequate, these events can erode decades of development and deeply affect society's welfare.

Preparing for this new era of climate challenges is critical for safeguarding the well-being of Europe's communities and economies. Many countries in the region have set ambitious goals, which require substantial investment to mitigate and adapt to the projected changes, such as the increased frequency and intensity of extreme weather events. While much needs to be done, financial resources are scarce, with many urgent and often competing priorities.

To respond to these challenges, focused and smart investments are needed in climate adaptation and disaster prevention and preparedness, accompanied by strengthening and adapting infrastructure, institutions, societies, and finance at different levels of government.

Focused – because while Europe has been taking steps to invest in disaster and climate resilience, critical sectors, including those providing civil protection and emergency response, remain highly exposed. If infrastructure fails—because a fire station is destroyed in an earthquake, critical evacuation routes are flooded, or hospitals are evacuated because of wildfires—people, homes and businesses cannot be saved, magnifying the impacts of an event. If public financing is severely affected—or even depleted—due to the impact of major catastrophic events, the government cannot provide timely emergency, recovery and reconstruction support to its populations and the economy.

Smart – because while preventive investments make clear economic sense, 18[18] more can be achieved using data and information to scale up prevention, preparedness and adaptation efforts in a cost-effective, and targeted manner. In an environment of constrained resources, the region will not be able to successfully manage current and future risks unless investments to prevent and prepare for disasters are prioritized. At the same time, disaster prevention and climate

15 Munich Re. 2023. Record thunderstorm losses and deadly earthquakes: The Natural Disasters of 2023. Link.
16 EC (European Commission). 2020. *PESETA IV*. Link.
17 Kerblat, Yann, et all. 2022. *Overlooked: Examining the Impact of Disasters and Climate Shocks on Poverty in the Europe and Central Asia Region*. Link.
18 World Bank and European Commission. 2021. *Economics for Disaster Prevention and Preparedness: Investment in Disaster Risk Management in Europe Makes Economic Sense*. Link.

adaptation efforts are closely interlinked and should be integrated to maximize the benefits of socioeconomic development and fiscal sustainability.

At the World Bank Group, we are modernizing our mission and instruments to ensure better support to countries globally and in Europe. In the region, the World Bank Group has been strengthening partnerships, providing financing and sharing knowledge to help communities manage the risks of disasters and climate change. Among these efforts, we support countries to modernize their policy and strategic frameworks, and prioritize, design and finance investments that strengthen disaster and climate resilience, including in critical infrastructure and emergency response services.

This series of analytical reports, produced as part of a partnership with the European Commission, attests to our commitment.

Building on results generated in 2021,[19] this set of reports provides new evidence, tools, and examples for countries in Europe to strengthen their disaster and climate resilience in a focused and smart manner. By highlighting aspects such as prioritized decision-making, understanding the costs of climate change, and risk-informed budgeting, these reports can be instrumental in developing and implementing nuanced policies and strategic investments that are attuned to the diverse hazards facing Europe. By embracing such new tools and approaches, we can ensure that communities are more resilient in the face of ever-evolving climate impacts and help secure a sustainable future for generations to come.

***Antonella Bassani***

Vice President, Europe and Central Asia
World Bank

19 World Bank and European Commission. 2021. *Economics for Disaster Prevention and Preparedness*. Link.

# Executive Summary

**Europe's risk profile and projected climate change impacts, concentration of population, and aging infrastructure and assets call for urgent action to improve resilience**. Europe is warming faster than any other region in the world, with recent disaster events—including floods, wildfires, heatwaves, and droughts across various parts of the European Union (EU)—indicating the intensification of climate extremes alongside ongoing global warming. Disasters have far-reaching effects, resulting in loss of lives, destruction of infrastructure, disruption of critical sectors and services, and impacts on public and private finance. Between 1980 and 2023, disasters in the EU affected nearly 50 million people and caused on average an economic loss of roughly €14 billion per year,[1] although, for example, in 2023, economic loss in Europe climbed up to €77 billion.[2]

**While European countries are taking major steps in enhancing disaster and climate resilience, catastrophic events reveal blind spots in critical sectors that provide emergency response services**. In the 2023 Türkiye earthquakes, 42 hospitals suffered severe and moderate damage and tens of emergency response buildings such as fire stations and emergency coordination centers were destroyed or severely damaged, along with ambulances, fire trucks, and search and rescue vehicles.[3] In August 2023, patients at the Alexandroupolis General Hospital in the Northeast of Greece, with a capacity of nearly 700 beds, had to be evacuated because of the approaching wildfire.[4] During the 2021 floods in Germany, four fire stations and a fire department's entire fleet of vehicles and equipment were destroyed in Altenahr.[5] In 2020, earthquakes in Croatia damaged 214 health sector buildings; one-quarter of them suffered moderate to severe or heavy structural damage.[6] Nine months later, another series of earthquakes damaged 20 civil protection (CP) buildings, five of them heavily,[7] along with emergency response equipment.

***Focused* and *smart* investments are needed to strengthen and adapt critical sectors in Europe to disaster and climate risks.** *Focused* actions are needed in terms of policy and investments for critical sectors to ensure the resilience of emergency infrastructure, services, and capacities. ***Smart*** actions

1 CRED and UCLouvain. 2024. *Emergency Event Database EM-DAT, 1980–2023. Link. See also EEA. 2023a. Economic Losses from Weather- and Climate-Related Extremes in Europe*. Link.; World Bank and European Commission 2021a.

2 Munich Re. 2023. *Record Thunderstorm Losses and Deadly Earthquakes: The Natural Hazards of 2023 [online]*. Munich Re: Munich, Germany. Link.

3 The surface area of collapsed and severely damaged buildings covered about 40,000 m2. See Government of Türkiye. 2023. *Türkiye Earthquakes Recovery and Reconstruction Assessment.* Link.

4 European Commission. 2023a. *ECHO Daily Flash of 23 August 2023.* Link.

5 Landesregierung Rheinland-Pfalz. 2023. *Der Wiederaufbau.* Link.

6 214 health facilities sustained damage in the March 2020 earthquakes (Government of Croatia. 2020a. *Croatia Earthquake Rapid Damage and Needs Assessment 2020.* Link.), and further 193 health facilities sustained damage in the December 2020 earthquakes (Government of Croatia. 2020b. *Croatia December 2020 Earthquake Rapid Damage and Needs Assessment 2020.* Link).

7 Government of Croatia 2020b. Link.

are needed, informed by risk data and analytics, to guide decision-making toward the high-priority areas and enable a strategic approach that maximizes efficiency and effectiveness in scaling up prevention, preparedness, and adaptation to disaster and climate risks.

**Recent disaster events revealed significant knowledge gaps and the need to better understand the risks faced by critical sectors and what actions countries can take to systematically, yet efficiently, mitigate and manage these risks.** This report helps close some of these gaps by providing guidance to decision-makers and practitioners on how to make focused and smart investments to increase the disaster and climate resilience of critical sectors. First, to inform EU-wide policy discussion and knowledge base, it highlights hotspots where assets of critical sectors (including emergency response, schools, hospitals, roads, and power lines) are exposed to multiple and single hazards including floods, wildfires, earthquakes, and landslides. Second, to support national and subnational policy and investment planning, this report provides tools and examples for investing in the disaster and climate resilience of critical sectors in a prioritized and risk-informed manner. Seven analytical tools, over 30 examples, and five case studies can guide decision-makers and practitioners to prioritize the most impactful actions in a resource-constrained environment and help scale up investments in risk reduction and preparedness of critical sectors, especially CP, and for emergency response-related infrastructure and services. Key definitions used in this report are highlighted below with a full glossary included up front in the report.

### BOX 1. KEY DEFINITIONS

**Critical sectors** comprise entities, infrastructure, assets, equipment, systems, and networks that provide an essential service in CP and emergency response, prevention, and preparedness. Traditionally, these include transport, energy, and water but increasingly banking, telecommunications, and others. In this report, CP and emergency response refers to fire and police stations, as well as health and education facilities due to their roles in emergencies. Critical sectors provide critical or essential services, which are considered crucial for the maintenance of vital societal functions, economic activities, public health and safety, or the environment. As a critical service, emergency services provide immediate and rapid assistance in situations of risk to people, private or public property, or the environment. Critical or emergency services are enabled through entities, infrastructure, assets (like buildings), equipment, systems, networks, and relevant human, financial resources, and other capacities.

**Disaster risk management** (DRM), through policies and measures, seeks to strengthen disaster and climate resilience. Key DRM efforts include keeping people and structures away from hazardous areas, making infrastructure more resilient, and having operational capacities to manage residual risks and respond to and quickly recover from disasters, such as by investing in early warning systems, contingency planning, public awareness, and readiness.

**Prioritization** is part of a broader decision-making process, which has several stages, including the development and use of a prioritization framework. Prioritization by public entities occurs at different governance levels focusing on policy and investments, location or type of assets and interventions—multi-hazard, hazard specific, or structural/nonstructural, infrastructure or social resilience related, and so on. Developing and using a prioritization framework requires decision-makers to consider various elements and criteria and how to combine them given specific policy context, objectives, stakeholder context, funding, timelines, and so on. Analytical tools are available to guide decision-makers in deciding over specific aspects and decision criteria.

**Resilience:** The ability of a system, community, or society exposed to hazards to prevent, protect against, respond to, resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

***Sources:*** *See glossary above.*

## Key Takeaways for Policy Makers

### FOCUS ON CRITICAL EMERGENCY SECTORS

**As Europe is increasingly challenged by climate change and economic pressures, investing in resilient critical sectors, including in CP and emergency response, has never been more urgent.** Critical sectors provide emergency response services to the society and the economy, saving lives and helping to minimize losses and disruptions as well as costs of recovery and reconstruction. Critical sectors, particularly emergency and CP response sectors, are at the forefront of disasters—whether it is the global COVID-19 pandemic which highlighted the need for quick and effective response to save lives or many recent disaster events in Europe such as floods in Germany and Belgium in 2021 and Slovenia in 2023; widespread wildfires in France, Greece, Italy, Portugal, and Spain (and other countries in the western Mediterranean but also northern Europe) in 2021 and 2023; severe droughts and extreme heat across Europe in 2022 and 2023; and a series of earthquakes in Croatia in 2020 and in Türkiye in 2021 and 2023. However, as noted above, critical sectors—their assets, equipment, staff, and systems—can also be at the center of disasters, with failure or disruption, leaving society more vulnerable to the impacts of disasters.

**Despite its importance for the society, there are no comprehensive data or analysis which would provide information on the current state of critical sectors in Europe considering their location, conditions, and current and future hazards.** Examples across Europe point to many common challenges including aged and poorly maintained infrastructure, which does not meet today's standards in terms of safety, functionality, and usability by professionals and beneficiaries. Modernization efforts do not address often compounding challenges in an integrating manner which would consider structural and functionality aspects as well as climate change adaptation (CCA) and mitigation needs. Importantly, critical infrastructures, such as buildings or roads, are often assessed individually instead of through a portfolio approach. This issue risks overlooking potential vulnerabilities related to lack of redundancy within a network of services and interconnectivity and cascading effects related to infrastructure, supply chains, and others.

**While critical infrastructure can be located by design in areas of increased hazard, to efficiently provide emergency support, it can also place critical infrastructure at higher risk of being damaged or disrupted during a disastrous event if the design and construction process did not adequately consider the risks.** The EU-wide analysis conducted as part of this report shows that CP and emergency response-related assets and education facilities, and roads and power lines, are exposed to multiple hazards including flooding, wildfire, earthquake, and landslides. Although only a small proportion of fire and police stations across the EU are exposed to multiple hazards, at the individual member state (MS) level, a different picture emerges. In some EU MSs, most emergency response assets are exposed to multiple hazards. In Cyprus, for example, 59 percent of fire stations are exposed to two hazards rated as high; the share is 58 percent in Greece and 43 percent in Croatia and Bulgaria, while the least exposed fire stations are in Lithuania, Estonia, Ireland, and Denmark. Analysis of 21,500 health care facilities across the EU found that 44 percent were exposed to one of the four hazards. The countries with the greatest proportion of health care facilities exposed to two or more hazards are again Cyprus (74 percent), Greece (65 percent), Croatia (48 percent), and Bulgaria (46 percent). Related specifically to road and power line infrastructure, the EU-wide exposure analysis shows that around half of the EU MSs have over 80 percent of roads and 70 percent of power lines exposed to high wildfire hazard. In view of seismic and landslide hazards, the numbers are less dramatic, but MSs still have thousands to tens of thousands of kilometers of network segments exposed to these types of risks.

**Beyond the information about exposure to multiple hazards, the EU-wide analysis also shows hotspots exposed to single hazards.** Floods, for instance, have the potential to inflict damage primarily on lower levels of critical facilities like hospitals or schools, while earthquakes pose a more severe threat of entire structural collapse. Even if buildings remain unscathed, the disruption of transportation routes or power lines could impede the rapid and efficient deployment of emergency services. It is therefore essential to highlight the substantial consequences arising from exposure even to a single hazard and address the wider vulnerabilities of CP assets in the context of disaster resilience planning and response strategies.

**While the EU-wide exposure assessment has limitations,[8] as explained in Chapter 1, the results clearly point to 'exposure hotspots' across the EU which require more detailed analysis and highlight next steps.** Understanding the exposure of critical sector assets, and focusing on these priority areas with further analysis, decision-makers can take actions to manage the highest risks and minimize potential impacts. Future research could help fill other existing data and knowledge gaps, notably regarding the condition of critical service assets, their criticality within networks or a portfolio of buildings, to better understand gaps in redundancy and interconnectivity and to better predict the impacts of climate change and compound risks. This initial analysis can also inform future analysis of the benefits and costs of investing in risk reduction, the need to locate new assets in lower-hazard areas, and/or the need for other resilience-enhancing measures.

## FOCUS ON SMART DECISION-MAKING

**In the face of substantial exposure, there are ways to strengthen disaster and climate resilience of critical sectors by focusing on prioritized and risk-informed approaches.** There is solid evidence that investing in disaster resilience in Europe makes economic sense and can deliver multiple benefits to society. For example, heatwave early warnings have been found to provide significant benefits; on average every euro invested returns €131 of benefits with the potential return as high as €246.[9] Measures focused on wildfire prevention, such as managing wildland-urban interfaces (WUIs), were found to have BCRs of 2.1 to 3.1; addition of fuel breaks in forested areas had a BCR of 12.[10] There are many low-regret or no-regret DRM investments, meaning they bring benefits under various scenarios and climate projections. They also offer clear benefits for community-level awareness programs, as this report shows.

**Global evidence shows that prioritization can make investments cost-effective, especially when considering likely impacts of climate change and focusing on risk-exposed assets.**[11] Considering the capital costs for critical infrastructure such as power, transport, and water and sanitation—which can be very high—it is estimated that with suitable and robust hazard data, strengthening priority assets would cost only US$11–65 billion (€10-60 billion) per year which is a fraction (3 percent) of the estimated total infrastructure investment needs.[12] In ECA countries (including EU-27), strengthening priority assets would cost about $457 million per year[13] – which is a fraction (4.8 percent) of the region's total infrastructure investment needs.[14] In EU-27 countries, strengthening priority assets would cost about $279 million per year, and the additional cost of resilience is even smaller at about 3.9 percent

8 An exposure analysis does not consider the structural vulnerability of people, buildings, or infrastructure, so it does not provide an estimate of the potential damage, loss, or disruption.

9 The mean benefit-cost ratio (BCR) is 131, with a range of 48–246. See, for details, World Bank and European Commission 2021b.

10 World Bank and European Commission 2021b.

11 Hallegatte, Stéphane, Jun Rentschler, and Julie Rozenberg. 2019. *Lifelines: The Resilient Infrastructure Opportunity*. Link.

12 Hallegatte, Rentschler, and Rozenberg 2019. Robust data refers to, for example, hazard data with adequate spatial resolution and return periods and updated or reliable enough to guide investment decisions.

13 The $457 million in resilience investment needs a year reflects a preferred spending scenario and resilience standard. The figure can range from $73 million to $1.8 billion a year for minimum/maximum spending scenarios with associated low/high resilience standards.

14 Hallegatte, Rentschler, and Rozenberg 2019. The estimate depends on minimum/maximum spending scenarios with associated low/high resilience standards.

of total infrastructure investment needs..[15] In practice, this means, for example, that in the transport sector network, it is crucial to understand which sections are most vulnerable to disaster and climate risks and which ones are most critical. This enables decision-makers to prioritize efforts with high resilience outcomes and comparatively small investment input.

**In the context of European critical sectors for emergency response, this report shows the importance of developing and using prioritization frameworks and tools to guide efficient resource allocation, risk reduction, and resilience building in the face of the evolving challenges and uncertainties.** Prioritization is part of a broader decision-making process which occurs at different governance levels focusing on policies and investments. Countries prioritize resilience within their national development plans whereby they identify measures and investments in national DRM or CCA strategies and within sectors whereby interventions are prioritized based on the specific location, hazard, or socioeconomic and environmental context. Developing and using a prioritization framework requires decision-makers to consider various elements or 'building blocks' and decide how to assemble these based on given policy context, strategic objectives, stakeholder consultation, funding, timelines, and so on. Analytical tools and approaches can help decision-makers find the right combination of elements and criteria that can guide them through the prioritization process toward a policy roadmap or investment plans. Further information is included in the 'Summary for Practitioners' section.

**The review of existing examples and case studies provides three key overarching recommendations for prioritization efforts related to critical sectors in Europe.** First, integrate disaster risk information and, as much as possible, future climate projections. Second, consider the criticality of networks/services or a portfolio of emergency response-related assets. Third, estimate benefits and costs of investing in prevention and preparedness. While a specific situation will determine the main key factors and criteria, following through on these three points can significantly contribute to generating knowledge and fill some of the existing gaps that limit Europe's ability to prevent, prepare, rapidly respond to, and recover from disasters.

## POLICY RECOMMENDATIONS

**To move the agenda on making critical services resilient, there is a need to act on the following key policy recommendations:**

a.) **Focus on resilient critical infrastructure and services—including the CP and emergency response sector—across policies, development strategies, and investment plans.** Resilient CP and emergency response infrastructure and services need to be an explicit priority, both across the policy and strategic investment frameworks and across different administrative levels. This focus will confirm commitment to the disaster prevention and preparedness agenda and enable commitment of funds and scale-up of actions, in line with relevant responsibilities.

b.) **Promote and fund research into critical sectors, to fill existing data and knowledge gaps.** Disasters across Europe show that critical infrastructure can fail when it is aged and poorly maintained or does not meet modern functionality and usability standards. Yet information about the condition of many critical assets and their capabilities to provide emergency services in case of different disaster scenarios is not available for most countries within the EU. This is particularly the case for EU MSs where many assets are exposed to multiple hazards. In parallel, there is a need to better understand the intensification of hazards under a changing climate (for example, floods, wildfires, extreme temperature, and drought). Improved risk information can feed into the development of policies and strategies and inform the prioritization of investments in critical sectors.

15 Hallegatte, Rentschler, and Rozenberg 2019. The estimate depends on minimum/maximum spending scenarios with associated low/high resilience standards.

c.) **Take smart and prioritized investment decisions to maximize benefits of investing in the resilience of critical sectors**. Limited resources need to be prioritized to maximize benefits. The focus in the coming decades needs to shift from disaster response to risk prevention and reduction, with an emphasis on avoiding new risks, reducing existing risks, and effectively managing residual risks. Decision-makers should make use of available tools and methodologies to guide and prioritize their decisions, assess expected benefits and costs, understand performance, and ensure alignment with the local context and community needs as well as climate change-related aspects. Rapid or phased approaches can be conducted in data-poor environments and can lead to more robust and comprehensive prioritization frameworks.

d.) **In line with the confirmed priorities, commit dedicated funds for upgrading, replacement, maintenance and operation, and energy efficiency of critical infrastructure and then track results.** Authorities play a central role in securing public safety and need to increase spending on ex ante prevention and preparedness measures, including upgrading of critical infrastructure at risk, proper operations and maintenance, robust evaluation and monitoring, stress testing, and regular updating of assets and capabilities in line with new research. In parallel, authorities should take advantage of opportunities both to review existing funding streams for potential adjustments that would direct funding to resilient critical sectors and to improve tracking of current levels of prevention and preparedness. Improved data on actual spending, along with examples of successful approaches, programs, and projects, can contribute to a virtuous cycle of positive change across different administrative levels.

e.) **As disaster and climate resilience is a cross-cutting and all-of-society effort, strengthen collaboration vertically and horizontally, both through and in support of the above efforts.** Society's resilience can be further reinforced by promoting a preventive culture and meaningfully involving a broad set of stakeholders—across national borders; across administrative levels; within relevant countries; within the public, private, and civil sectors; and across critical sectors and academia. There are many examples of relevant initiatives and efforts. Going forward, better collaboration can help speed up and improve preparation, planning, and implementation of prevention and preparedness investments, and in this way scale up impactful programs to increase disaster and climate resilience.

## Summary for Practitioners

**Critical sectors provide essential services that enable vital societal functions, economic activities, public health and safety, and protection of the environment.** The ability to prevent, prepare for, and respond to disasters lies at the core of the CP and emergency response sector, but health, education, transport, energy, water, telecommunications, and other sectors also play an important role in DRM by providing emergency health care, shelter, evacuation routes, connectivity, critical utilities, and so on. Emergency services can be hampered when the systems they rely on are disrupted or threatened, facilities or equipment is damaged, or professional or volunteer staff are hurt or cannot fulfil their tasks.

**The achievement of *resilience*—that is a state of being able to prevent, protect against, respond to, and recover from an event[16]—relies on DRM investments across several dimensions.** These include infrastructure, institutions, society, environment, and the economy/public finance, among others; all need investments before a disaster

16 UNDRR 2017.

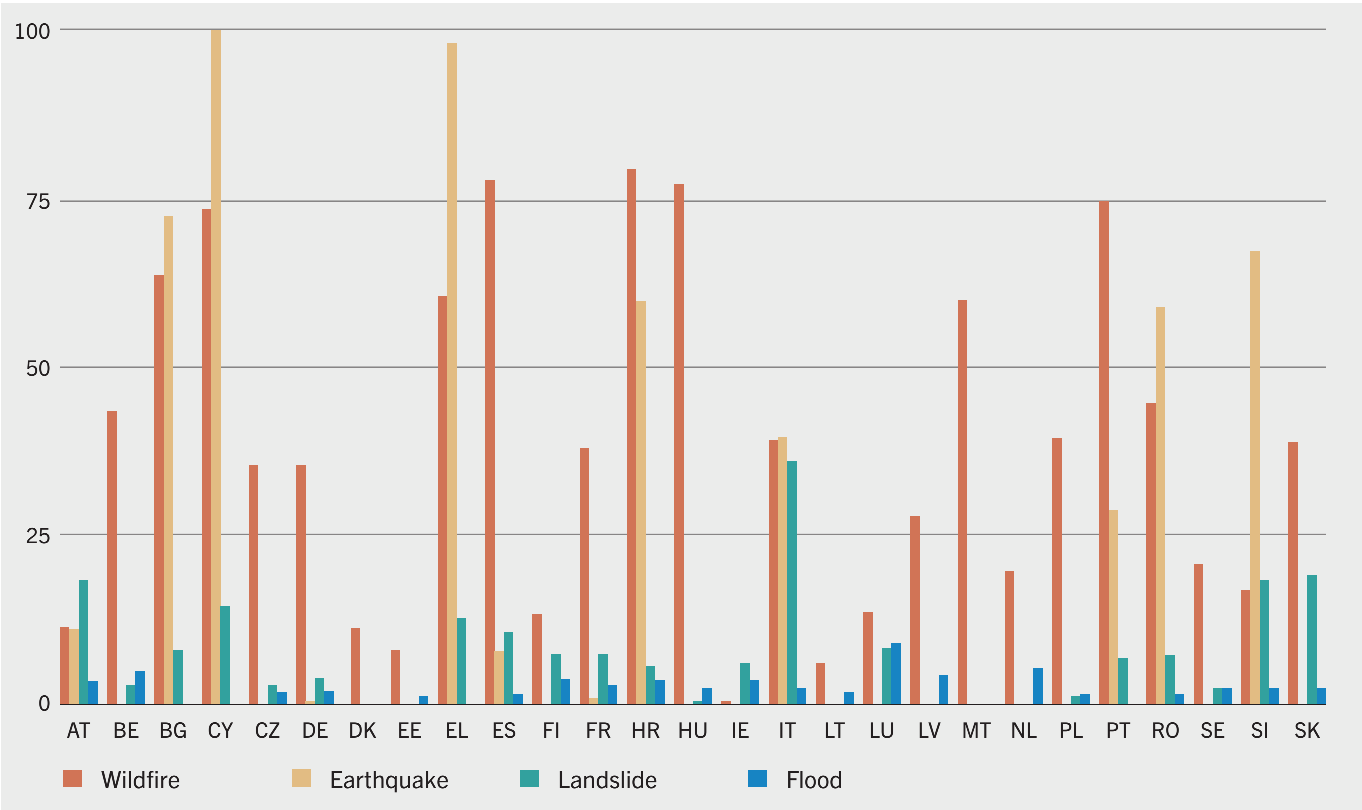
event (ex ante). Risk management integrates various approaches to minimize the potential impacts of hazard, including prevention and mitigation (to avoid hazards and reduce negative impacts), preparedness and readiness to respond (to manage impacts), and preparedness for resilient recovery (to manage the aftermath of disaster). There are different types of DRM investments, and they span different phases of the DRM cycle. DRM efforts are also closely linked to CCA and related efforts, as they share a common goal and deal with reducing vulnerabilities and increasing resilience to hazards and risks.

### Hotspots: Understanding the Exposure of Critical Assets to Multiple Natural Hazards

**Given existing data gaps, it is impossible to assess at the EU level if and how critical infrastructure is at risk from disasters and climate change, fully considering hazard, exposure (location), and vulnerability information (condition).** However, it is possible to understand the exposure of assets to natural hazards to get the 'big picture' and identify 'exposure clusters' on an EU-wide scale to deploy subsequent actions and further analytics. This report contributes to addressing some of the existing knowledge gaps by aggregating available information on selected hazards, critical sectors, and population data. Using an EU-wide approach in establishing hazard intensity thresholds and consistent data, it enables the comparison within and between EU countries to gain insights and directions for future research and actions.

**EU-wide analysis shows that emergency response-related assets, such as fire and police stations and health and education facilities, are exposed to a range of natural hazards, and many are exposed to multiple hazards.** In half of the EU MSs, fire stations are exposed to high levels of wildfire, landslide, flood, or earthquake (see Figure 1), and 2,300 fire stations across the EU are exposed to two hazards at high levels. The countries with the highest proportion of fire stations exposed to multiple hazards are in Cyprus (15 percent), Greece (8 percent), and Croatia (5 percent). Additionally, over 40 percent of police stations in Cyprus (59 percent), Greece (58 percent), Croatia (43 percent), and Bulgaria (43 percent) are exposed to high levels of two of the analyzed hazards.

**Figure 1.** Proportion of fire stations exposed to high levels of each assessed hazard

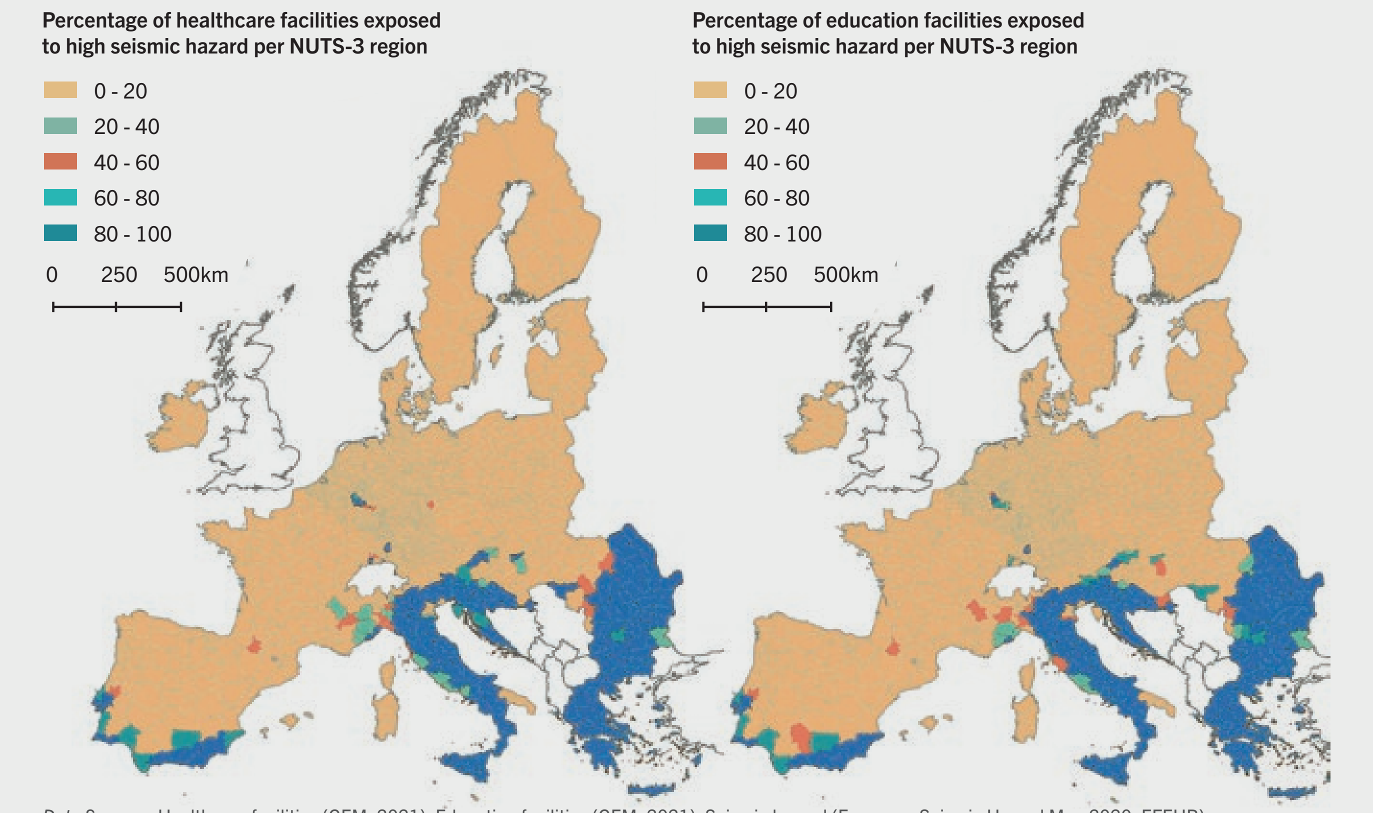



*Source:* World Bank.

**Considering individual hazards, the analysis reveals that half of the MSs have over 40 percent of their fire and police stations, schools, and hospital buildings in areas exposed to high wildfire hazard.** Across five MSs (Germany, France, Poland, Italy, and Spain, ordered from lowest to highest proportion of exposure), this amounts to over 8,000 assets; for many more MSs, this means that hundreds to thousands of such assets are exposed to high wildfire hazard. Across the EU, over 52,000 emergency response-related buildings (32 percent) are in areas classified in this analysis as high wildfire hazards and 17,000 (10 percent) as very high hazards. Across all MSs, almost 3,500 emergency response-related assets are exposed to flooding of greater than half a meter in a 1-in-10-year river flood event. Exposure to high seismic hazards is more concentrated; eight MSs (Greece, Cyprus, Bulgaria, Croatia, Slovenia, Romania, Italy, and Portugal, ordered from the highest to lowest proportion of exposure; see Figure 2). Concentrations of exposure to high seismic hazard: Health care facilities (left) and education facilities (right) have over 35 percent of their emergency response-related assets exposed to potentially damaging seismic hazard, including over 1,000 educational facilities in Greece, Romania, and Italy. About 9,000 assets are exposed in Italy, and between a few hundreds and a couple of thousands in the remaining countries.

**Eleven countries have hundreds of assets in areas of high landslide susceptibility, and in large countries—namely Italy, Austria, France, and Germany—this can mean thousands of assets exposed.**

**Figure 2.** Concentrations of exposure to high seismic hazard: Health care facilities (left) and education facilities (right)




*Data Sources:* Healthcare facilities (GEM, 2021), Education facilities (GEM, 2021), Seismic hazard (European Seismic Hazard Map 2020, EFEHR), Administrative units (GISCO)

*Source:* World Bank.
*Note:* NUTS3 = Third division in Nomenclature of Territorial Units for Statistics, a hierarchical classification system used by the EU for statistical and administrative purposes. NUTS3 is most detailed level and is often used for localized statistical and administrative purposes.

**Related specifically to road and power line infrastructure, EU-wide mapping shows that around half of the EU MSs have over 80 percent of roads and 70 percent of power lines exposed to high wildfire hazard.** In six MSs, 70 percent of roads are exposed to high seismic hazard, equating to thousands of kilometers of road network exposed. In Slovenia, Greece, Bulgaria, and Croatia, more than 90 percent of roads are exposed to this level of seismic hazard. In Greece, Cyprus, Slovenia, Bulgaria, and Croatia, over 90 percent of power lines are exposed to high seismic hazard. In Spain, Ireland, Slovenia, Portugal, Austria, and Greece, more than 80 percent of roads are in areas of high landslide susceptibility. In Greece, Slovenia, Spain, and Bulgaria, 70 percent or more of power lines are in areas of high landslide susceptibility—equal to thousands to tens of thousands of kilometers of network segments. While this analysis does not specify exposure down to the individual kilometer of road or power line, it does indicate that the majority of network segments are at risk of damage and disruption if hazardous events occur.

**Understanding the exposure of critical assets to potential disasters enables decision-makers to deploy subsequent analyses.** For example, by assessing the vulnerability of emergency response assets, CP authorities can prioritize actions and allocate resources more efficiently during disasters. Similarly, gauging the susceptibility to specific hazards can contribute to enhanced disaster preparedness, ensuring uninhibited deployment of emergency services.

**As with any analysis of this scale, there are limitations to the approach, detailed under the 'Terminology and Methodology' section.** The hazard data sets are of differing resolution, were created using different probabilistic and deterministic methods, and use different metrics to record hazard levels. At this scale, some information is unavailable, specifically on vulnerability, flood protection, and fuels that could contribute to wildfire. Nonetheless, the quantitative exposure assessment can be used to inform future analysis.

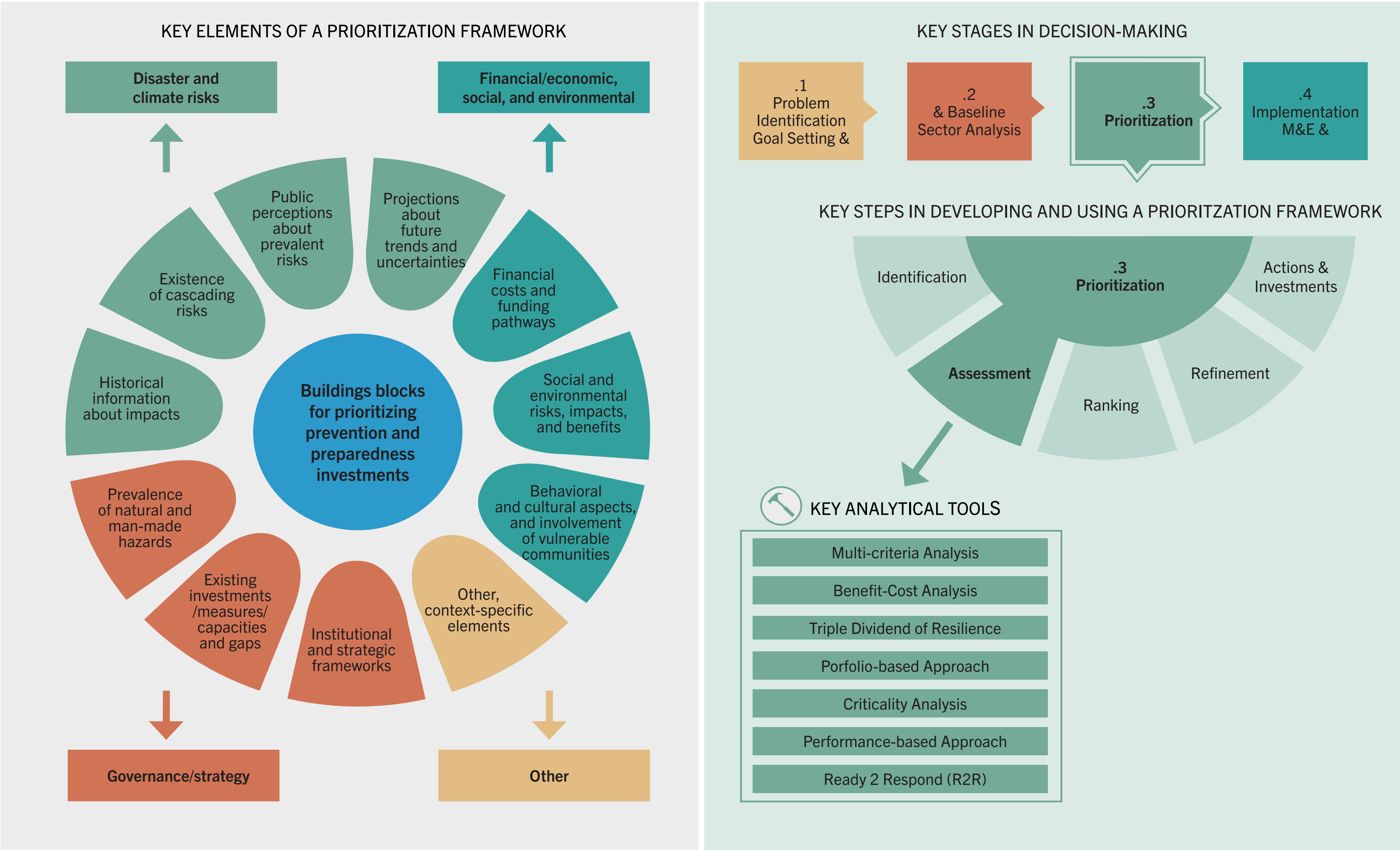
## RESILIENCE: PRIORITIZING CRITICAL INFRASTRUCTURE AND SERVICES

**Given potentially substantial needs and limited resources, prioritization of DRM investments is an indispensable process to identify impactful, targeted, and cost-effective improvements.** Prioritization and use of an evidence-based approach are important for strengthening the disaster and climate resilience of critical sectors, as their effective services help safeguard lives, protect assets, and preserve economic stability. As demonstrated in this report through examples and case studies, prioritization is relevant for different levels of decision-making, whether for strategic planning (such as for EU, national, or subnational strategies and plans) and for investment planning related to critical sectors and at different scales, including the project level. These methodologies are also relevant and can be considered to support fulfilment of EU obligations, such as those laid out in the Critical Entities Directive (2022/2557),[17] as well as the achievement of the EU disaster resilience goals.

**Figure 3 illustrates the key stages in decision-making, key steps in developing and utilizing a prioritization framework, key elements within a framework, and key analytical tools that can help integrate these elements and provide answers to selection criteria.**

17 EU 2022.

**Figure 3.** Process and considerations for prioritizing DRM investments




*Source:* World Bank.
*Note:* DRM = disaster risk management; M&E = Monitoring and evaluation.

**Prioritization is part of a broader decision-making process, which will vary based on the local context, policy, and/or investment objectives.** This generally includes key stages: (I) problem identification and goal setting; (II) baseline and analysis; (III) development and use of a prioritization framework; and (IV) implementation, monitoring, and evaluation.

**Within this four-stage decision-making process, the development and use a prioritization framework (stage III) follows separate steps.** These generally include (1) identification of assessment criteria, (2) assessment weighting of investment options based on the criteria, (3) ranking or scoring of options, (4) refinement of prioritization results with expert feedback and additional analysis, and (5) development of an investment action plan or roadmap and its implementation.

**Also, as part of developing and using a prioritization framework, several key elements need to be considered.** These include (a) the governance and strategic frameworks; (b) disaster and climate risk information; (c) financial, economic, environmental, social aspects; and (d) context-specific factors. Solutions must be context specific, tailored to the unique geographic, climatic, economic, and social conditions of a sector or an area.

**Several relevant analytical tools and approaches are available to prioritizing investments in critical sectors, and depending on their complexity are able to reflect a range of these key elements, criteria, data, and information.** The tools have their own specificities and are applicable at different stages of the policy or investment preparation cycle. For example, disaster and climate risk-based approaches in combination with a comprehensive exposure/vulnerability assessment (at the appropriate level/scale) and analysis of climate scenarios could be a first step and contribute to the identification of gaps in DRM measures. Governance/strategy- and DRM-related approaches (e.g., portfolio-/performance-based) come into play once information about existing DRM measures and gaps has been gathered. Economic and social approaches (for example, TDR or BCA) would also play a role at a certain stage of the prioritization process.

This report focuses on seven such tools, many of them complementary. While all approaches require a certain level of data and information, even in the context of data limitations, there are ways to use these tools in a rapid manner and/or build gradually from initial analysis. A short description of the key seven analytical tools for prioritization is included in Box 2. Seven key analytical tools for prioritizing resilience investments in critical sectors, with an overview of respective strengths and weakness included in Chapter 2 (see Table 1). The report showcases more than 30 examples of successful prioritization within critical sectors in different countries and five new case studies demonstrating the ability to conduct analytics in data-poor environments, in a rapid manner, and by combining various approaches. Chapter 3 provides a detailed overview of these examples and case studies.

**BOX 2.** SEVEN KEY ANALYTICAL TOOLS FOR PRIORITIZING RESILIENCE INVESTMENTS IN CRITICAL SECTORS

**Multi-criteria analysis (MCA)** can identify priorities within strategies and investment plans across different levels of decision-makers. In recent years, it has been used by several EU MSs for developing national DRM plans. In Greece and Bulgaria, this approach made it possible to bring together different priorities across different hazards and sectors; the results informed the identification of subsequent programs, projects, and priorities, such as those under the countries' respective National Recovery and Resilience Plans (NRRPs). See page 38 for details.

**Benefit-cost analysis (BCA)** focuses on monetizable benefits and costs linked to projects/investments to determine economic justification. It is widely applied in public policy decision-making, particularly for infrastructure. The Portugal case study used a comprehensive BCA to understand the potential benefits of the Safe Village - Safe People (SVSP; Portuguese: *Aldeia Segura - Pessoas Seguras*) program. See page 39 for details.

**Triple dividend of resilience (TDR) approach** expands the traditional BCA approach and considers three types of benefits: avoided losses when disasters strike, stimulated economic activities and innovation arising from reduced risks, and generated socioeconomic and environmental co-benefits. Whether for a portfolio of assets or individual programs/projects, investment decisions can be greatly enhanced by using a TDR approach; the Croatia case study applied this approach. See page 39 for details.

**Portfolio-level assessments** can clarify the condition and risk levels of a portfolio of assets (such as fire stations, schools, or hospitals). Existing lessons learned from Romania and a new case study in Croatia show the potential of using this kind of analysis and associated results for prioritizing integrated investments in upgrading/reconstruction of CP and education buildings at high risk. See page 40 for details.

**Criticality analysis** can improve the understanding of the resilience of networks—such as transport, energy, or health—and impacts of shocks within it. The Romania case study shows how information on flood risk and criticality can be used to better target investments. See page 41 for details.

**Performance-based approaches** can complement different types of analysis by focusing on specific performance indicators. The Bulgaria case study used a performance-based analysis to integrate heat and wildfire risks into the prioritization framework circumscribed by the national DRM plan. See page 41 for details.

**Ready2Respond (R2R) approach** can quickly yet systematically illuminate the key strengths and weaknesses of CP and emergency response systems by covering key capacities, namely (a) legal and institutional framework, (b) personnel, (c) facilities, (d) equipment, and (e) information. In the Croatia case study, the self-assessment was used to generate a rapid yet comprehensive overview of the strengths and weaknesses of the preparedness and response system at the country and city levels. See page 42 for details.

## A Call for Action across Different Administrative Levels

**Policy makers across different levels should consider the findings and recommendations of this report within the broader agenda of disaster and climate resilience.** There is a need for action across all levels that considers the following:

**Europe needs strong political commitment and champions for focused and smart investments in critical sectors to make them withstand current and future disasters.** Several recent events have revealed the existing weaknesses of critical sectors, thus highlighting the urgency for action. Prioritizing investments in prevention and preparedness often involves making difficult trade-offs between competing needs and objectives. Balancing short-term priorities with long-term objectives is thus crucial and demands strong political will and policy support for improving the resilience of these critical sectors.

**Prioritization processes require sufficient capacities and technical expertise as well as coordination among stakeholders**. Training and education are needed to ensure decision-makers and practitioners across critical sectors are well equipped to be able to use risk information, consider various elements (such as portfolio of assets and criticality of networks), and estimate benefits and costs.

**There are still many knowledge and data gaps in the understanding of the current risks and investment needs for disaster prevention and preparedness in Europe.** Disaster and climate risk information is not systematically used to inform policies or investment planning, though there are many opportunities to collect relevant data and use different risk analytics. Also, improvements are needed in the collection and tracking of data and information on disaster prevention and preparedness, climate change adaptation investments, and post-disaster expenditures during the response and recovery process. This information is critical to better understand the current levels of investments, their targeting, effectiveness and efficiency, and other aspects.

## NATIONAL AND SUBNATIONAL LEVELS

**Given national and subnational authorities' mandates for policy setting, investment planning, and management/use of critical sectors, these authorities have many opportunities for taking actions, including the following:**

- Review their existing strategies, investment plans, funding processes, and programs to identify gaps related to the integration of disaster and climate risks and to strengthening of critical sector resilience. Strategic and investment plans should explicitly integrate disaster and climate risk information that is aligned with international and EU frameworks. For example, there is an opportunity to integrate such considerations in the Strategy on the resilience of critical entities, as required under Article 4 of the Critical Entities Directive (2022/2557).[18]

- Continue to invest in robust research related to disaster and climate resilience**.** Support the systematic collection, analysis, and uptake of risk information.

- For investment planning and funding decisions, apply risk-informed prioritization frameworks that fit specific contexts and needs.

- Most importantly, commit funds to enhance the resilience of critical sectors—including those related to CP and emergency response—according to the respective mandate. These may include a range of measures, such as rehabilitation/reconstruction of assets, investment in new technologies, capacity building, training, and sector-specific research.

- Funding programs and tracking mechanisms should focus on critical sectors and provide information to all stakeholders so that they can be meaningfully engaged in the design, implementation, and monitoring of investments.

## EU LEVEL

**At the EU level, there are also many opportunities to help address knowledge and data gaps, promote sharing of information, improve quality/targeting of funds, and promote collaboration across stakeholders:**

- Key strategies and action plans at the EU level need to consider disaster and climate risks and spotlight critical infrastructure sectors, including CP and emergency response. The Critical Entities Directive 2022/2557 takes a step forward in this direction, as an overarching framework that addresses the resilience of critical entities in respect of all hazards, whether natural or man-made, accidental, or intentional, combined with taking steps to achieve the EU Disaster Resilience Goals (DRGs) – particularly Goal 5: Secure – Ensuring a robust civil protection system.

- This report highlights some of the existing data gaps and shows the need for EU-wide research on disaster and climate change as well as critical infrastructure and services and comparable data to be accessible by EU MSs.

- Through its policies, funding, and initiatives, the EU could in parallel promote the uptake of risk analytics as well as prioritization frameworks through capacity building and sharing of good practice. This step should in turn help facilitate and enable smart investments with multiple co-benefits.

- Better tracking of prevention and preparedness investments that contribute to disaster and climate resilience would help fill some of the gaps in the levels of funding available for specific hazards, measures, or areas at risk.

- Moreover, continued efforts to foster collaboration among EU MSs and subnational actors—through sharing of good practice, data, and information—would be beneficial.

18 EU 2022.

# Introduction

## Why Focus on Critical Sectors?

**Given current and projected climate change impacts and aging infrastructure as well as population growth across Europe, having robust critical sectors has never been more important.** In 2023, economic losses amounted to €77 billion in Europe,[1] and between 1980 and 2023, disasters in the European Union (EU) affected nearly 50 million people and caused on average economic losses of roughly €14 billion per year.[2] In 2021, Germany and Belgium were affected by severe floods, causing loss of lives, affecting thousands, and costing over US$20 billion.[3] The same year, multiple wildfires in France, Greece, and Spain as well as in some southeastern countries destroyed hundreds of thousands of hectares of land. In 2022, heatwaves in Europe resulted in about 16,300 deaths, accounting for over half of the total death toll globally that year due to natural hazards.[4] Finally, the summer of 2023 brought a series of widespread wildfires across Greece, Italy, Portugal, and Spain and widespread drought conditions in the western Mediterranean as well as northern Europe[5] while severe storms and floods occurred in Croatia, Italy, Greece, and Slovenia, with several concurrent disasters within one country. At the same time, Europe is warming faster than any other region in the world and is increasingly subject to extreme disaster events.

**Impacts on assets, systems, networks, and professional and volunteer personnel within critical sectors can reduce the capacity of the service or system to respond, thereby hampering overall emergency processes when they are most needed.** For example, during the 2023 earthquakes in Türkiye, at least twelve hospitals suffered damage. A study of their post-event performance and seismic engineering highlights the importance of strengthening such facilities; those that had seismic base isolation continued the provision of services almost immediately while some without this feature could not because of extensive nonstructural damage (even though none collapsed).[6] Moreover, about 40,000 m$^2$ of emergency response-related buildings, as well as 26 vehicles such as ambulances, fire trucks, and search and rescue vehicles, were destroyed or severely damaged.[7] In March 2020, earthquakes in Croatia damaged 214 health sector buildings, with one-quarter sustaining either moderate-to-severe or

1 Munich Re 2023.
2 CRED and UCLouvain 2024. See also EEA 2023a; World Bank and European Commission 2021a.
3 CRED. 2021. "Extreme Weather Events in Europe." *CRED Crunch Newsletter* 64. Link.
4 CRED. 2023. "Disasters Year in Review 2022." *CRED Crunch Newsletter* 70. Link.
5 Toreti et al. 2023. *Drought in Europe June 2023*. Link.
6 Qu, Zhe, Feijian Wang, Xiangzhao Chen, Xiaoting Wang, and Zhiguang Zhou. 2023. "Rapid Report of Seismic Damage to Hospitals in the 2023 Turkey Earthquake Sequences." *Earthquake Research Advances* 3 (4). Link.
7 Government of Türkiye 2023.

heavy structural damage,[8] and nine months later, further earthquakes damaged—among other types of infrastructure—20 civil protection (CP) buildings, five of which heavily.[9] This affected the emergency response significantly and led to the relocation of operations. The 2009 earthquake near L'Aquila in Italy severely affected the local medical infrastructure; for example, the main trauma hospital in the area suffered major structural damage including to its accident and emergency unit and had to be replaced by two field hospitals in conjunction with aerial evacuation to remove seriously injured patients to hospitals outside the disaster area.[10]

**Critical sectors—including CP and emergency response—provide essential services, yet investments in the CP sector are lagging and hard to track.** Actions for disaster prevention, preparedness, response, and recovery form part of essential services which enable maintaining vital societal functions, economic activities, public health and safety, and protection of the environment. The ability to prevent, prepare for, and respond to disasters lies at the core of the CP and emergency sector, but health care, education, transport, energy, water, telecommunications, and other sectors play an important role in disaster risk management (DRM), by providing emergency health care, shelter, evacuation routes, critical utilities, and so on. The global COVID-19 pandemic has highlighted the need for prevention and preparedness as well as the necessity to respond quickly and effectively to save lives. Despite this importance, several common obstacles hinder investments in resilience and critical sectors including political economy challenge and coordination failures; lack of incentives for service providers to bear the cost of disruptions or protect the ecosystem; inadequate data, skills, or tools; and affordability and financing constraints.[11]

**Emergency services can be hampered by disruption to critical systems they rely on, perceived threats, and when damage occurs to their immediate facilities.** A report on flooding of the UK National Health Service facilities, including hospitals and ambulance stations, documented 176 flooding incidents in one year (2021–2022) in the United Kingdom, affecting medical services and emergency response due to roads being flooded as well as flooding at hospital sites.[12] In Alexandropoulos, Greece, in 2023, patients were evacuated and treated on a ferry when wildfire came close to a hospital and nearby clinic,[13] a situation which was also seen in Santa Rosa, California, United States, in 2017.[14] In the 2011 Christchurch earthquakes in New Zealand, several fire stations were severely damaged, with crews having to operate out of portable buildings in the subsequent years, and the high level of damage triggered the strengthening of design criteria for station buildings and surrounding access to ensure uninterrupted operations in future events.[15]

**Enhancing the resilience of critical sectors is crucial for maintaining societal functions and safeguarding against a wide range of potential risks.** Despite their importance, there are no comprehensive and comparative data across Europe. Some common challenges observed across Europe in the CP and emergency response sector specifically include the following:

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8 214 health facilities sustained damage in the March 2020 earthquakes (Government of Croatia 2020a), and further 193 health facilities sustained damage in the December 2020 earthquakes (Government of Croatia 2020b).

9 Including the building of the Croatian Mountain Rescue Service (Government of Croatia 2020). Six CP buildings were damaged in Sisak city (half of them unusable), nine in Petrinja city (three of them unusable), and two in Glina, both unusable.

10 Alexander, D. E. 2010. "The L'Aquila Earthquake of 6 April 2009 and Italian Government Policy on Disaster Response." *Journal of Natural Resources Policy Research 2* (4): 325–342. Link.

11 Hallegatte, Rentschler, and Rozenberg 2019.

12 Jeffrey, Jack. 2023. *NHS Underwater*. Report for about Round Our Way. Link.

13 Alexandroupolis, Alexandros Avramidis. 2023. "Newborn Babies among Dozens of Patients Evacuated from Hospital to Ferry to Escape Raging Greek Wildfire." *The Independent*, August 22, 2023. Link.

14 TRACIE. Health care Emergency preparedness Information Gateway. The Last Stand: Evacuating a Hospital in the Middle of a Wildfire. Link.

15 Kupec, J., and J. S. Muirson. 2021. *New Zealand Geotechnical Society Symposium. Rebuilding With Resilience: The Story of The Fire Station Rebuilds in Christchurch.* Link.

- *Exposure.* While critical infrastructure can be by design located in areas of increased hazard, to efficiently provide emergency support, this can place critical infrastructure at higher risk of being damaged or disrupted during a disastrous event if the design and construction process did not consider disaster and climate risks.

- *Age and vulnerability.* Some buildings were not designed or retrofitted to withstand the impacts of certain natural hazards. This can especially be the case for buildings and infrastructure constructed before the introduction and implementation of modern building codes (such as Eurocode 8).[16] Many CP and emergency facilities are likely to have outdated components or structures that are more susceptible to failure.

- *Poor maintenance.* Inadequate maintenance practices can lead to the deterioration of infrastructure, making it more vulnerable to natural hazards or other disruptions. Poor maintenance/ lack of investments is frequently linked to limited national/subnational budget allocations and/or complex funding arrangements. In many cases, past renovations did not fully address the range of issues and hazards; for example, upgrading for energy efficiency may not systematically integrate improvements in seismic resilience or fire safety.

- *Operational readiness and functionality.* Operational readiness relates to capacities of users, access to training, functionality of buildings and equipment, including information and communication technology systems, interoperability with other systems, such as early warning and alert systems, and so on. Depending on the nature/type of the infrastructure, the facility may have specific requirements for functionality, including facilities for male/female associates (for example, fire fighters) or areas to congregate (for example, professionals to train volunteers[17]). Often these aspects were not considered in the past when the facilities were originally constructed.

- *Cascading and other effects.* Interconnected infrastructure systems mean that a failure in one sector can cascade into others. For example, a power outage could affect telecommunications and transportation, creating a domino effect. In some cases, critical systems may also lack redundancy, leaving them vulnerable if one component fails. These issues are often overlooked if the status of structures is assessed individually instead of through a portfolio or network approach. Reliance on international suppliers for components or materials can introduce additional vulnerabilities or disruptions (as observed during the COVID-19 pandemic).

**Addressing these weaknesses requires a comprehensive approach that includes investments in resilience to natural hazards, modernization, interconnectedness, and robust regulatory frameworks.** Limited financial resources hinder necessary upgrades, maintenance, and security measures, making critical sectors and their infrastructure more susceptible to failures. The midterm review of the Sendai Framework for Disaster Risk Reduction (SFDRR) highlights the need for governments and stakeholders to create knowledge and environments that incentivize mobilization of public and private investment in resilient infrastructure.[18] This requires quantification of the multisectoral benefits of such investment, drawing on the expertise and insights of diverse stakeholders, including private institutions.

**While CP/emergency response is a supporting competency, the EU has a mandate to encourage cooperation between their member states (MSs) to improve the effectiveness of systems for preventing**

16 This is the case, for example, in Romania—World Bank. 2023d. *Feature Story: Strengthening Disaster Risk Management in Romania: Building Modern, Inclusive, Near-Zero Energy, and Disaster-Resilient Fire Stations*. Link.

17 A lesson learned in the Zagreb earthquakes in 2020 was that there were no facilities to provide training to volunteers.

18 UNDRR. 2023a. *The Report of the Midterm Review of the Implementation of the Sendai Framework for Disaster Risk* Reduction 2015–2030. Link.

**and protecting against natural or man-made disasters.**[19] The EU should (a) support and complement MSs' action at the national and regional levels in risk prevention, preparation of their CP personnel, and response to natural or man-made disasters within the EU; (b) promote swift, effective operational cooperation within the EU between national CP services; and (c) promote consistency in international CP work. The Union Civil Protection Mechanism (UCPM) provides a framework for coordinated disaster response, which includes the deployment of resources, such as transport capacities as well as technical teams.[20]

**In line with this, many efforts have been made toward investing in disaster and climate resilience.** Most recently, in line with the revision of the European Commission (EC) UCPM (Decision No. 1313/2013/EU), a set of EU-wide Disaster Resilience Goals (DRGs) were approved in 2023. The specific five voluntary goals for EU MSs are as follows: Goal 1 Anticipate - Improve risk assessment, anticipation, and risk management planning; Goal 2 Prepare - Increase risk awareness and preparedness of the population; Goal 3 Alert - Enhance early warning; Goal 4 Respond - Enhance the UCPM response capacity; and Goal 5 Secure - Ensure a robust CP system. Also, a set of disaster scenarios, as well as the Wildfire Prevention Action Plan, were developed. There has also been greater focus on critical infrastructure, including the Critical Entities Resilience Directive (CER) 2022/2557,[21] which provides several opportunities for strengthening critical infrastructure and EU MSs to undertake relevant disaster risk reduction (DRR) and climate change adaptation (CCA) measures.

**The EU's 2021–2027 Multi-Annual Financial Framework (MFF) provides several opportunities for investing in DRM and CCA.** These include special funds under the Recovery and Resilience Facility (RRF) and the NextGenerationEU (NGEU) instrument as well as under the budget headings for single market, innovation, and digital; cohesion, resilience, and values; natural resources and environment; and neighborhood and the world. Also, the implementation of the EU Green Deal is a priority, under which CCA, post-COVID-19 recovery, and DRM are envisaged.[22] Figure 4 provides an overview of available opportunities under the 2021–2027 MFF. This report offers guidance on investing in critical sectors for decision-makers in Europe, providing them with tools and examples to prioritize actions that promote resilience.

**A rapid review of the availability and use of funds showed that many countries use available EU funds to enhance disaster and climate resilience.** However, in the absence of systematic and comprehensive tracking databases and information, it is not possible to draw out consolidated results across all EU MSs but rather just to highlight known cases or where data are available. For example, tracking progress with risk prevention investments between 2014 and 2020, the EC reported around €10 billion investments in CCA and risk prevention and management, with €7.5 billion from the EU budget, including the Cohesion Policy Funds and rescEU, as well as national co-financing.[23] Per the European Regional Development Fund (ERDF) and Cohesion Fund (CF) climate tracking for 2021–2027, DRM and CCA-related interventions include energy efficiency in public infrastructure (€8.1 billion), housing (€4 billion), and enterprises (€2.6 billion) as well as prevention and management of floods and landslides (€6.2 billion), climate change measures of prevention and management (€3.9 billion), prevention or management of climate-related risks such as fires (€1.9 billion), and services linked to local climate engagement and climate change (€806 million).[24]

19 EU. 2016. *Treaty on the Functioning of the EU*. Link.

20 The UCPM was established in 2001 (by EU Decision 1313/13) and serves as the primary instrument related to DRM within the EU, providing various types of support and resources, including experts and voluntary pre-committed capacities across the DRM cycle, including providing specific funding to develop prevention and preparedness to disasters through grants.

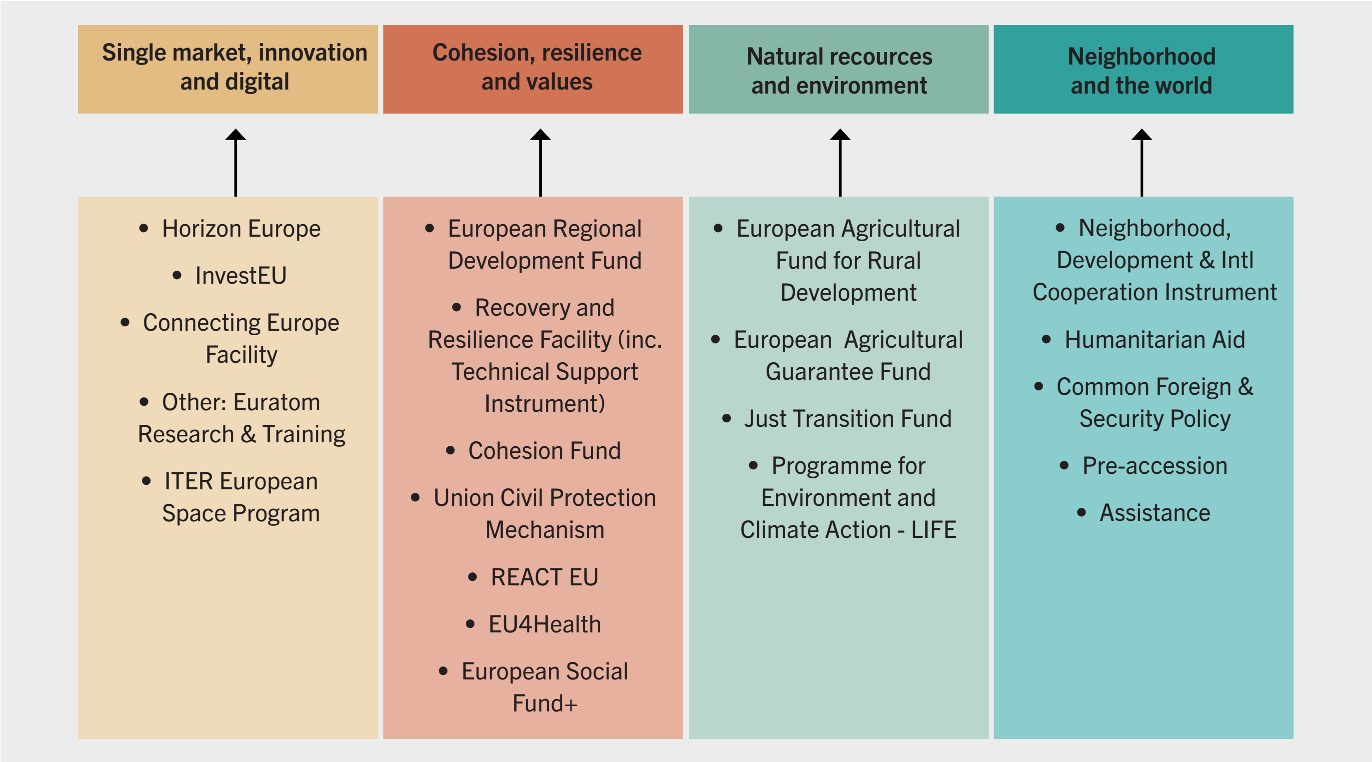
21 EU 2022b.

22 EC. 2019. *The European Green Deal COM/2019/640*. Link.

23 EC. 2024. *Cohesion Policy: Preventing Risks*. Link.

24 The figures are reported based on available data on the European Commission website. Cohesion data. Link.

**Figure 4.** Opportunities for investing in DRM and CCA under the EU's 2021–2027 MFF




*Source:* World Bank.
*Note:* ITER = International Thermonuclear Experimental Reactor; REACT EU = Recovery assistance for cohesion and the territories of Europe.

**In response to the COVID-19 global pandemic,** the EU's RRF[25] was established as an instrument to mitigate the economic and social impacts. Based on available information, 40 percent of the facility's actions are disaster and climate related and include DRM-specific areas such as risk awareness and strengthening of CP capacity and management of specific risks, with several examples in Box 3. Nearly half of the EU MSs have utilized the RRF and their subsequent National Recovery and Resilience Plans (NRRPs) for financing DRM-related activities.

25 EC. 2023c. *The Recovery and Resilience Facility.* Link.

**BOX 3.** EXAMPLES OF PRIORITIZATION OF DISASTER AND CLIMATE RISK ACTIVITIES IN NRRPS

**Bulgaria,** which has devoted 58.9 percent of the NRRP to support climate objectives, has envisaged measures to improve emergency communications, including the digitalization of the national 112 system and extending the national coverage of the Terrestrial Trunked Radio (TETRA) system, utilized in disaster and crisis management. (*Source:* Government of Bulgaria. Recovery and Resilience Mechanism. Link; EC. Bulgaria's Recovery and Resilience Plan. Link)

**Belgium's** NRRP is estimated to be the second greenest NRRP in the EU and has committed 51 percent to sustainability and climate, offering also €1.3 billion for the energy-efficient renovation of buildings, as well as measures to tackle drought. (*Source:* Government of Belgium. NextGenBelgium. Link)

**Croatia**, which has allotted 40.3 percent of the NRRP to support climate objectives, has planned €789 million in energy efficiency and post-earthquake reconstruction of buildings as well as DRR measures in water management (€124.6 million for risk reduction and €33.1 for green infrastructure). (*Source:* Government of Croatia. Initiative: Renovation of Buildings. Link; EC. Croatia's recovery and resilience facility. Link)

**France** devotes 46 percent of the NRRP to support climate objectives, including climate adaptation measures, and various risk reduction measures, such as investments in water management infrastructure and seismic risk prevention in outer regions. (Source. EC. France's Recovery and Resilience Plan. Link)

**Lithuania** has dedicated 37.8 percent of the NRRP to climate objectives, including elements of risk management, such as to support the restoration of degraded peatlands. (*Source:* EC. Lithuania's Recovery and Resilience Plan. Link)

**Portugal** has allocated 38 percent of the NRRP to climate objectives, including measures related to create a national public response to urgent and temporary accommodation needs arising from unexpected or unforeseeable events such as natural hazards, fires, and pandemics. (*Source:* Government of Portugal. NRRP. Link; EC. Portugal's recovery and resilience facility. Link)

**Romania** has committed 41 percent of the NRRP to climate objectives, including rehabilitation of existing defense lines in accordance with the Floods Directive and the National Strategy for Flood Risk Management. (*Source:* Government of Romania. Green light from the EC for the NRRP. Link; EC. Romania's recovery and resilience facility. Link)

## Why Focus on Smart Decisions and Investments?

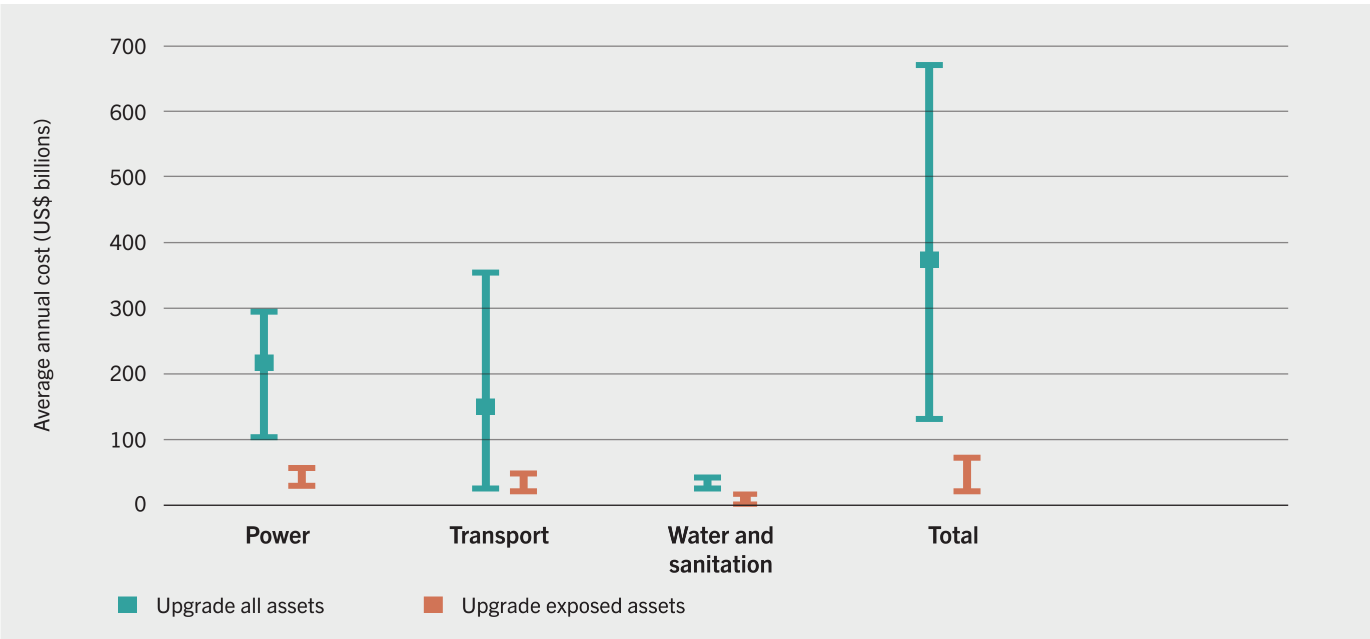
**Prioritization serves as a compass in the journey from data to decisions, guiding organizations toward wise resource allocation and strategic investments.** In simple terms, prioritization means deciding what is important and tackling those things first. The process ensures that finite resources, be it time, money, or manpower, are directed toward endeavors that align with overarching goals and objectives. The significance of prioritization lies in the prudent allocation of resources toward activities or initiatives that yield the most impact or value, often referred to as 'smart' investments. By embracing prioritization as a foundational principle, decision-makers can navigate the complexity and ensure that efforts are focused where they can make the greatest difference.

**Smart investments are not solely confined to economic benefits but extend to any allocation of resources aimed at maximizing returns or outcomes.** Prioritization plays a pivotal role in this regard by guiding decision-makers to identify opportunities with the highest potential for success or value creation. By carefully analyzing data and considering various factors, organizations can pinpoint areas where investments are most likely to yield favorable results or address the most pressing challenges.

**Data are vital for prioritization and smart investments because they provide the necessary insights to identify opportunities, assess risks, and allocate resources wisely.** By analyzing data, decision-makers can understand underlying conditions, make better-informed decisions, and prioritize initiatives with the highest potential for success and value creation. Getting from data to decisions involves three related research fields: data collection, data analysis, and prioritization. The process entails gathering relevant information from diverse sources and subjecting it to rigorous scrutiny to extract meaningful findings. Once the data have been comprehensively analyzed, the next step is to establish prioritization criteria—such as strategic alignment, socioeconomic and environmental benefits, and financial and opportunity costs—which serve as guiding principles for evaluating potential initiatives. Decision-makers can then proceed to evaluate and rank the available options and identify those that promise the biggest impact/value. Through collaborative discussions and informed judgments, decisions are made regarding which initiatives to pursue and allocate resources accordingly. Ongoing monitoring and adaptation ensure that chosen courses of action remain aligned with objectives and deliver the desired outcomes.

**In the context of current and future disaster risk, the needs for investment in efforts to strengthen disaster resilience are substantial while facing severe budget constraints with many competing priorities.** Global evidence shows that prioritization can make investments cost-effective, especially when considering likely impacts of climate change and focusing on risk-exposed assets.[26] Considering the annual incremental capital costs for critical infrastructure such as power, transport, and water and sanitation—which can be very high—it is estimated that strengthening priority assets would cost only US$11–65 billion per year which is a fraction (3 percent) of total infrastructure investment needs (see Figure 5).[27] Per this global data, in EU-27 countries, the additional cost of resilience would be about 3.9 percent of total infrastructure investment needs.[28] In practice, this means that, for example, in the transport sector network, it is critical to understand which sections are most vulnerable and which ones are most critical. This enables decision-makers to prioritize efforts with high resilience outcomes and comparatively small investment input.

**Figure 5.** Incremental annual capital cost for more resilient infrastructure for 2015–30




*Source:* Hallegatte, Rentschler, and Rozenberg 2019.
*Note:* 'Cost' here is the average annual capital investment cost between 2015 and 2030. The circles represent the median, and the vertical bars represent the full range of possible incremental costs. The range is linked to the uncertainty on how much will be invested in infrastructure during the period (and the technologies chosen).

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26 Hallegatte, Rentschler, and Rozenberg 2019.
27 Hallegatte, Rentschler, and Rozenberg 2019.
28 Hallegatte, Rentschler, and Rozenberg 2019. In the Europe and Central Asia region, as defined by World Bank' regional definition, strengthening priority assets would cost about US$457 million per year which is a fraction (4.8 percent) of the region's total infrastructure investment needs. The US$457 million in resilience investment needs a year reflects a preferred spending scenario and resilience standard. The figure can range from US$73 million to US$1.8 billion a year for minimum/maximum spending scenarios with associated low/high resilience standards.

## Objectives, Structure, and Broader Relevance of This Report

**The objective of this report is to provide guidance to decision-makers and practitioners to make focused and smart investments to increase the disaster and climate resilience of critical sectors.** This is achieved by highlighting the importance of critical infrastructure, identifying hotspots that are most exposed to multiple hazards, and providing tools and examples for decision-makers on how to prioritize actions for a more resilient Europe.

**Although preventive investments make clear economic sense,[29] investments in prevention and preparedness are still limited compared to post-disaster spending.** For example, in Romania (and many other countries in Europe), most fire stations were built over 50 years ago, before modern seismic design codes, and have already been identified as needing retrofit to avoid first responders being "among the first casualties, significantly reducing their ability to help others."[30] Moreover, these older buildings may not meet the needs of today's bigger and more connected cities or lack facilities for female professionals who may have not be eligible for employment in these buildings at the time of construction. While funds have been allocated, there is a need for major scale-up of such investments. Moreover, only few countries track budget on prevention and preparedness and no such comprehensive data are available at the EU level either.

**Several knowledge gaps hinder scaling up resilient investments in critical sectors.** Decision-makers do not always have access to quality information/data, policy support, tools, frameworks, and so on to address gaps in a prioritized and cost-effective manner. For example, information about the exposure and vulnerability of infrastructure and critical services may not be available, and even if this information is available, it may not necessarily be in a way that can be used effectively to prioritize investment planning. Decision-making needs to consider several elements such as multiple hazards, service delivery and functionality, socioeconomic considerations, future climate change projections, urbanization trajectories, and other uncertainties. Yet, despite complexities, general principles and examples are available for countries to take necessary steps today.

**This report closes some of these gaps and provides tools and examples for decision-makers on how to prioritize investment in critical sectors for a more resilient Europe.** First, the report highlights the hotspots of critical assets that are exposed to multiple hazards to inform the broader EU-wide policy discussion. This report generates knowledge, including insights into the levels of exposure of critical infrastructure in Europe to multiple hazards, and provides guidance on utilizing available risk information to prioritize interventions. To support national/subnational-level planning, this report provides evidence and examples for investing in disaster and climate resilience in a prioritized and risk-informed manner. This includes a description of available prioritization tools and frameworks and existing and new operational examples using such approaches that can guide decision-makers in the UCPM countries and participating states (PSs). This information is purposefully set in the general context of DRM investments and investment decision-making. In doing so, this report is relevant to those involved in investment planning related to disaster and climate resilience, those engaged in DRM and emergency response, and different stakeholders including public policy makers/fund providers across various administrative levels, public officials, practitioners, the private sector, academia, civil society organizations, and others.

29 As demonstrated by World Bank and European Commission (2021a).
30 World Bank 2023d.

## STRUCTURE OF THE REPORT

**The report's structure and content are summarized in Figure 6.** The Executive Summary highlights key messages for policy makers and practitioners. The Introduction provides the overall context and description of the methodology. Chapter 1 provides a summary of the EU-wide exposure analysis of assets of select critical sectors, followed by Chapters 2 which focus on the general DRM and investment theoretical framework, while Chapters 3 and 4 provide existing examples and new case studies to facilitate risk-informed, smart decision-making. while the Chapter 5 provides an overarching summary of the key results along with policy recommendations and suggestions for next steps at different decision-making levels.

**Figure 6.** Report's structure and content

**EXECUTIVE SUMMARY**
Key message for policy makers and practitioners

**INTRODUCTION**
Why focus on critical sectors, objectives, structures, methodology

**Chapter 1:**
**REGIONAL EXPOSURE ANALYSIS**
Understanding exposure of critical emergency response assets across the EU

**Chapters 2:**
**PRIORITIZATION PROCESS & TOOLS**
Understanding the overall process (roadmap), key elements, and analytical approaches

**Chapters 3 and 4:**
**PRIORITIZATION EXAMPLES AND USE CASE STUDIES**
Showcasing existing examples and select use cases to demonstrate and encourage uptake

| BULGARIA USE CASE | CROATIA USE CASE | PORTUGAL USE CASE | ROMANIA USE CASE | CROATIA CASE STUDY |
|---|---|---|---|---|
| **Multi-criteria analysis** | **Triple Dividend of Resilience** | **Spatial vulnerability & benefit cost analysis** | **Criticality network analysis** | **Ready to Respond approach** |
| • National-level prioritization | • National & local level prioritization | • National-level prioritization | • National-level/ local level prioritization | • National & local level prioritization |
| • Cross-sectoral | • Civil protection sector | • Civil protection sector | • Transport sector | • Civil protection sector |
| • Multi-hazard, heat & wildfire risk | • Seismic risk and energy efficiency | • Wildfire risk | • Flood risk | • Multi-hazard |

**CHAPTER 5: CONCLUSION**
Key results, takeaways, and recommendations

*Source:* World Bank.

### BROADER RELEVANCE OF FINDINGS

**This study complements and is aligned with EC research and activities on DRM.** It aims to inform ongoing flagship activities under the EU-wide DRGs, particularly Goal 1 focusing on risk information and planning and Goal 5 focusing on ensuring a robust civil protection system as well as ongoing efforts related to the development of disaster scenarios, specifically those capable of causing multi-country transboundary effects, to improve cross-sectoral disaster management planning at the EU level.

**The EU-wide exposure analysis can inform future risk analytics efforts.** The EU-wide exposure analysis gives an indicative assessment which can help prioritize further research at the EU, multi-country, country, or subnational level. The exposure analysis related to the wildfire hazard in particular can also be informative for the ongoing discussions on the development of an EU-wide Wildfire Prevention Action Plan,[31] especially related to data gaps and limitations as noted earlier in this chapter.

**Information on smart prioritization can guide the preparation/implementation of investment programs** related to prevention and preparedness at various levels of decision-making (for example, EU programs, national programs, and multi-country efforts), which are led by relevant actors (governments, line ministries, CP agencies, and so on).

**The examples and case studies contribute to improving the knowledge base and technical capacity to use risk information to prioritize investments.** The report considers necessary data on assets, methodologies, and best practices for various hazards and complexity levels of analytics and understanding of different trade-offs and how to consider multi-hazard and sustainability factors in prioritization of interventions. With a focus on critical sectors, including the CP sector and other sectors relevant to emergency service provision, this study can also be relevant for the implementation of the CER Directive (2022/2557)[32] and the amended Network and Information Systems (NIS2) Directive (2022/2555).[33]

## Terminology and Methodology

**This report draws on a range of DRM and climate change-related terms and concepts fully aligned with global/European frameworks and strategies, as listed in the glossary at the beginning of this report.**

**While several definitions are available, resilience refers to a multidimensional concept that involves the capacity of individuals, communities, organizations, and systems to anticipate, prepare for, respond to, recover from, and adapt to various shocks, stresses, or disturbances.** Resilience can be achieved through investments across several dimensions, including key ones such as infrastructural, institutional, social, environmental, and economic/financial.[34]

**DRM broadly refers to designing, implementing, and evaluating strategies, policies, and measures.** Their goal is to improve the understanding of disaster and climate risk, foster resilience, and promote improvement in disaster preparedness (including early warning and awareness), response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life,

31 EC. 2022a. *Informal Ministerial Meeting on Reinforcing Wildfire Preparedness and Response*. Link.
32 EC. 2021c. *Critical Infrastructure*. Link. The directive seeks to ensure that "critical entities are able to prevent, resist, absorb and recover from disruptive incidents, including those caused by natural hazards, accidents, terrorism, insider threats, or public health emergencies." EU 2022b. Link.
33 EU. 2022a. *Directive 2022/2555/EU*. Link.
34 Jha, Abhas, Todd Miner, and Zuzana Stanton-Geddes. 2013. Building Urban Resilience: Principles, Tools, and Practice. Directions in Development: Environment and Sustainable Development. Link.; Assarkhaniki, Z., A. Rajabifard, and S. Sabri. 2020. "The Conceptualisation of Resilience Dimensions and Comprehensive Quantification of the Associated Indicators: A Systematic Approach." *International Journal of Disaster Risk Reduction* 51: 2020. Link.

and sustainable development.[35] Risk management integrates various approaches to minimize the potential impacts of hazard. This includes spatial approaches, that is, avoidance/limitation of risk through site selection and land use planning (for example, away from hazards); physical resilience ensured through building codes and sustainable standards; mitigation protection (such as protection walls); operational resilience, such as contingency planning, redundancy and diversity in critical systems, inspection/stress testing, maintenance, and upgrading; and warning and alert systems, community engagement, and public awareness. By adopting a combination of these measures, the resilience of critical sectors can increase significantly. Tackling complex hazards, such as floods, wildfires, earthquakes, droughts, and extreme heat, necessitates collaboration across various sectors and stakeholders.

**DRM and CCA are closely linked as they share a common goal and both deal with reducing vulnerabilities and increasing resilience to hazards and risks.** DRM efforts contribute to CCA efforts and vice versa, with CCA more specifically focusing on the process of adjusting to live in a changing climate and making efforts to reduce the risk from the harmful impact of current or expected climate change impacts and climate-induced hazards. The goal of enhancing the ability to manage current and future disaster impacts is a common one.

**This report focuses on the resilience of selected critical sectors—and decisions—which can lead to scaling up of ex ante prevention and preparedness investments.** Accordingly, Chapter 1 provides an overview of the current levels of exposure of assets in critical sectors to a range of hazards at the EU level. Chapter 2 focuses on knowledge on DRM prioritization process and framework, and the rest of the report focuses on practical (examples/case studies) and policy recommendations on scaling up investments in areas that can inform decisions at the country/subnational level.

## EU-WIDE EXPOSURE ANALYSIS

**The location of CP infrastructure is important and relies on strategic planning and coordination to ensure that emergency response facilities are optimally situated to protect and serve their communities.** CP infrastructure that is close to communities helps reduce response time,[36] while resilient connections (whether by road or telecommunications) with other emergency centers, hospitals, or sites for evacuation (such as schools) help facilitate collaboration, evacuation, and coordination during emergencies. CP infrastructure needs to have reliable and resilient access to transportation networks to reach affected areas and consider existing and future risks, population structure and dynamics (for example, special needs groups), urban and land use planning, and broader environmental issues.

**A consistent exposure assessment was undertaken across the EU to understand how emergency response-related buildings (police and fire stations, education, and health care facilities) and critical infrastructure (roads and power lines) are exposed to four key hazards: wildfire, river flooding, landslides, and earthquake.** Beyond fire stations, police stations, hospitals, schools, and roads and power lines are considered in this analysis as they play a major role in the prevention, preparedness, response, and recovery processes. While there are several definitions, this selection is in line with the EC's understanding that critical sectors which provide essential services are crucial for the maintenance of vital societal functions, economic activities, public health and safety, or the environment and that the

35 Adjusted from World Bank and European Commission (2021a). UNDRR (2023) defines DRM as "the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses."

36 Lucas dos Santos Cabral et al. 2018. *Response Time in the Emergency Services: Systematic Review*. Link. The authors note that the World Health Organization recommends response in less than eight minutes. The United Stated Emergency Medical Services Act standard is that 95 percent of emergency requests should be served within 10 minutes in urban areas and within 30 minutes in rural areas.

resilience of these assets is critical in the sustaining of a resilience of a system, community, or society.[37]

**This analysis can be used to identify 'exposure hotspots' at the EU level where assets are highly exposed to wildfire, flood, earthquake, and landslide, with a focus on exposure to multiple hazards.** While it may only take one hazard to severely damage an asset, the identified concentrations of exposed assets can be prioritized for further targeted analysis and eventual investments.

**The exposure analysis involves overlaying asset information with hazard maps to analyze the number of assets exposed to different levels of hazard.** Hazard is represented using 'return period hazard maps' showing the maximum estimated hazard intensity (for example, flood depth) at a location for a given annual frequency of occurrence. In cases where these are not available—as is generally the case for wildfire and landslide due to data limitations—maps that show an index of classified risk or hazard are used. Exposure information is represented as point locations (for buildings) and linear networks (for roads or power lines).

**The benefits of an exposure assessment rather than a full risk assessment in this case include the relative simplicity of analysis, which enabled coverage of all EU MSs.** Similar geographic coverage with a full risk assessment would not be possible in this project. The analysis in this report requires fewer structural attributes to be assigned to assets than for a full risk assessment, as this analysis does not seek to estimate the amount of damage and loss to the assets or population. The advantage of this analysis is that it reduces the required analytical resources, making the EU-scale assessment more viable across multiple hazards and asset classes to support the more detailed case study analysis of later components while directly providing decision-making support.

**The analysis uses public and consistent asset and hazard data sets, where possible, using the outputs from EC analysis.** Results describe the number (or length) and proportion of assets exposed for each of and all MSs and at the NUTS3 level.[38] Results are presented for each asset type/category and hazard and for combined assets and multi-hazards. In addition, a literature review was conducted summarizing the availability of information on natural hazards and climate and disaster risk in the EU. The following is a short summary of the key steps taken (see Annex 1 for further details).

**However, the EU-wide nature of this analysis and availability of data introduces issues which limit the application of results for local-scale decisions and make this analysis useful for policy discussions primarily at the EU level and a starting point to undertake further localized analysis.**

1. *The coarse scale of hazard data describing a localized phenomenon.* This is especially true of the wildfire data used. The data were selected to provide consistent region-wide coverage, but that comes with the use of relatively low-resolution land use information. For that reason, localized differences in wildfire potential are not well represented.

   - This can result in a large area being characterized as high hazard (therefore more assets being considered exposed to high hazard), whereas the assets may be near to be not in a high-hazard area.

   - To address this, high-resolution hazard mapping conducting for smaller extents (for example, national or subnational) including fire line mapping, would be required.

37 EU 2022b.

38 NUTS3 is the third division in Nomenclature of Territorial Units for Statistics, a hierarchical classification system used by the EU for statistical and administrative purposes. NUTS3 is most detailed level and is often used for localized statistical and administrative purposes.

2. *The absence of flood protection in the flood hazard data set.*[39] Information on levels of flood protection (which might describe an area as protected by defenses against the 1-in-50-year flood) is generally poor and limits the accuracy of flood hazard models.[40] For this reason, the results of exposure and risk analytics draw on 'un-defended' flood hazard maps.

3. *The absence of asset-level protection,* such as seismic engineering and building codes, community or property-level flood protection, defensible space and roof or eaves modification to reduce the chance of smoke ingress and ignition of building materials in wildfire, and nearby slope stabilization, which could reduce the risk to a building, even though it might be in an area of high hazard.

4. *The lack of an available official EU-wide or even consistent EU MS-level data set* describing the location of fire, police, health care, and education facilities, and road/power network infrastructure means that the asset data used are modeled or sourced from publicly available data sets. There may be discrepancies between the number and locations of those assets contained in the sources used and official data.

**Also, the results presented here are subject to the hazard (intensity) thresholds used;** what is defined here as 'high hazard' is subjective and may vary depending on the purpose of the analysis, the types of assets being assessed, and the analysts' judgment. The 'frequency component' (that is, the selected return period hazard maps used) or choice of hazard index used can also vary according to preference, analytical need, or data availability. High hazard is defined here for landslide using the original susceptibility levels in the landslide data and for wildfire using an index derived from fire danger and burnable fuel availability. High flood hazard uses a 0.5 m depth threshold and very frequent hazard of 1 in 10 years, and for earthquake a threshold of ≥MMI VI is used, corresponding to strong shaking causing light damage (for more details, see Annex 1).

## HAZARD-SPECIFIC CONSIDERATIONS

**Related to wildfire, the result of the analysis is based on the EC Joint Research Centre (JRC) pan-European wildfire assessment data.** It is important to note that this analysis indicates the number of assets in an area of high wildfire hazard, based on fire weather index data, past fire occurrence data, and the presence of burnable fuel in the local environment. It does not consider asset-level protection (for example, structural protection or defensible space). There may be some assets counted that are protected from fire due to property-level protection, but this analysis gives an indicative assessment which can help prioritize further research and investment.

**Related to floods, this analysis indicates the number of assets in an area of high flood hazard, which is defined here as exceeding 0.5 m depth with a 10 percent annual chance of occurrence (1-in-10-year return period [RP10]).** The analysis does not consider community- or property-level flood protection that could mitigate flooding, because flood protection information is not implemented in the flood hazard model data used, due to a lack of information on protection in general and the EU-wide scale of the flood data. While many locations in Europe are expected to have flood defenses protecting against floods of this frequency, the RP10 flood hazard map is used to identify assets which are exposed to the most frequent floods. Sensitivity testing with the 1-in-100-year return period (RP100) flood hazard map showed that across the EU, 162 (of 21,500) more health care facilities are exposed to over 0.5 m flood depth using RP100 (in total 610 facilities or 2.8 percent) compared to using RP10 (in total 448 facilities or 2.1 percent), omitting the effects of flood protection. The greatest absolute increase at the MS level is in France (47 more,

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39 Alfieri, L., Salamon, P., Bianchi, A., Neal, J., Bates, P. and Feyen, L. 2013. *Advances in pan-European flood hazard mapping.* Hydrol. Process., 28: 4067-4077. Link.

40 Scussolini P, Aerts JCJH, Jongman B, Bouwer LB, Winsemius HC, de Moel H, and Ward PJ. 2016. FLOPROS: *an evolving global database of flood protection standards.* Nat. Hazards Earth Syst. Sci., 16, 1049–1061, Link.

to 227 or 4.1 percent of the total) and the biggest relative increase occurs in the Netherlands, where exposure increased from 4.9 percent to 9.4 percent (or 23) of health care facilities exposed to over 0.5 m depth in RP100 compared to RP10.

**Related to earthquake, this analysis indicates the number of assets in an area of high-seismic hazard, based on an EU-wide probabilistic seismic hazard assessment.** It does not consider property-level seismic engineering and building codes, which are likely to mitigate any damage from ground shaking, particularly in key response facilities.

## STEPS IN THE ANALYTICAL PROCESS

**Step 1: Asset layer.** The considered asset types included digital data sets of police stations, fire stations, road networks, education and health care facilities, and power and communication networks. Where possible, consistent exposure data on assets were used from EC sources and loaded into geographic information system (GIS) software.

**Step 2: Hazard layer.** Hazards considered in the analysis included wildfire, landslide, and earthquake (floods in progress). EU-wide consistent digital hazard maps were used to describe the distribution of maximum expected hazard intensity for each of the analyzed hazards: earthquake ground shaking (peak ground acceleration, g), wildfire (fire danger, index), and landslide (susceptibility, index). These were loaded into the GIS with the above exposure data.

**Step 3: Spatial overlay.** Using spatial methods, for example, sampling raster values and intersections, the exposure data and hazard were overlaid. The maximum hazard intensity of the index value from (2) was assigned to each attribute in the exposure data sets (1). This is repeated for each hazard on each exposure data set, so each CP asset has a maximum hazard intensity value for each hazard type. The full analytical routine is provided in Annex 1.

**Step 4: Results generation.** The per-attribute hazard intensity values were grouped by specified intensity thresholds, which were determined per hazard, to identify those exposed to (for example) high, moderate, and low hazard (for more information on the definition of intensity thresholds utilized in the analysis, see detailed per hazard in Annex 1) and aggregated by the NUTS administrative unit. The aggregate number and proportion of assets exposed to each threshold were exported by sector and hazard to summarize distribution of assets and exposure hotspots.

These four key steps are summarized in Figure 7:

**Figure 7.** Four-step approach for EU-wide exposure analysis


*Source:* World Bank.

**As with any analysis of this scale, there are limitations to the approach.** The open data sets used may be incomplete or contain inaccuracies in the geolocation of individual assets. The hazard data sets are of differing resolution, created using different probabilistic and deterministic methods, and record hazard levels using different metrics (for example, continuous values for flood depth and seismic ground shaking versus classified index values for landslide and wildfire). These approaches and metrics differ necessarily due to the different processes available in the state-of-the-art analysis of each of these hazards. Finally, the assessment of each hazard is subject to hazard-specific issues of scale and localization, which arise from the associated physical processes. National-level analysis could reduce the uncertainties in exposure assessment, but at the national scale it is more feasible to undertake full risk assessments to estimate damage and loss to assets.

## EXAMPLES AND CASE STUDIES OF PRIORITIZED INVESTMENTS TO INFORM DECISION-MAKERS AND INVESTMENT PLANNERS

**A literature review of existing methodologies and frameworks supported the selection of existing examples and generation of new case studies presented in this report.** The desk review focused on over 30 existing examples/studies that were considered to have high relevance for all EU MSs and UCPM PSs and candidate countries. The five case studies (Bulgaria, Croatia [two cases], Portugal, and Romania) were selected with the objective of exemplifying most relevant prioritization tools at different levels of decision-making and helping the operationalization of such approaches:

1. **Multi-criteria analysis (MCA)** to inform national DRM planning and showcasing ability to integrate both multi-hazard and additional heat and wildfire risk information (Bulgaria)

2. **Triple dividend of resilience (TDR) approach and a rapid portfolio-based analysis** for CP assets considering seismic and energy efficiency (Croatia)

3. **Vulnerability/spatial analysis and comprehensive benefit-cost analysis (BCA)** considering different scenarios for wildfire risk prevention ('Safe Village - Safe People' [Portuguese: Aldeia Segura - Pessoas Seguras, ] program) (Portugal)

4. **Criticality/vulnerability analysis** for the transport sector focusing on floods (Romania)

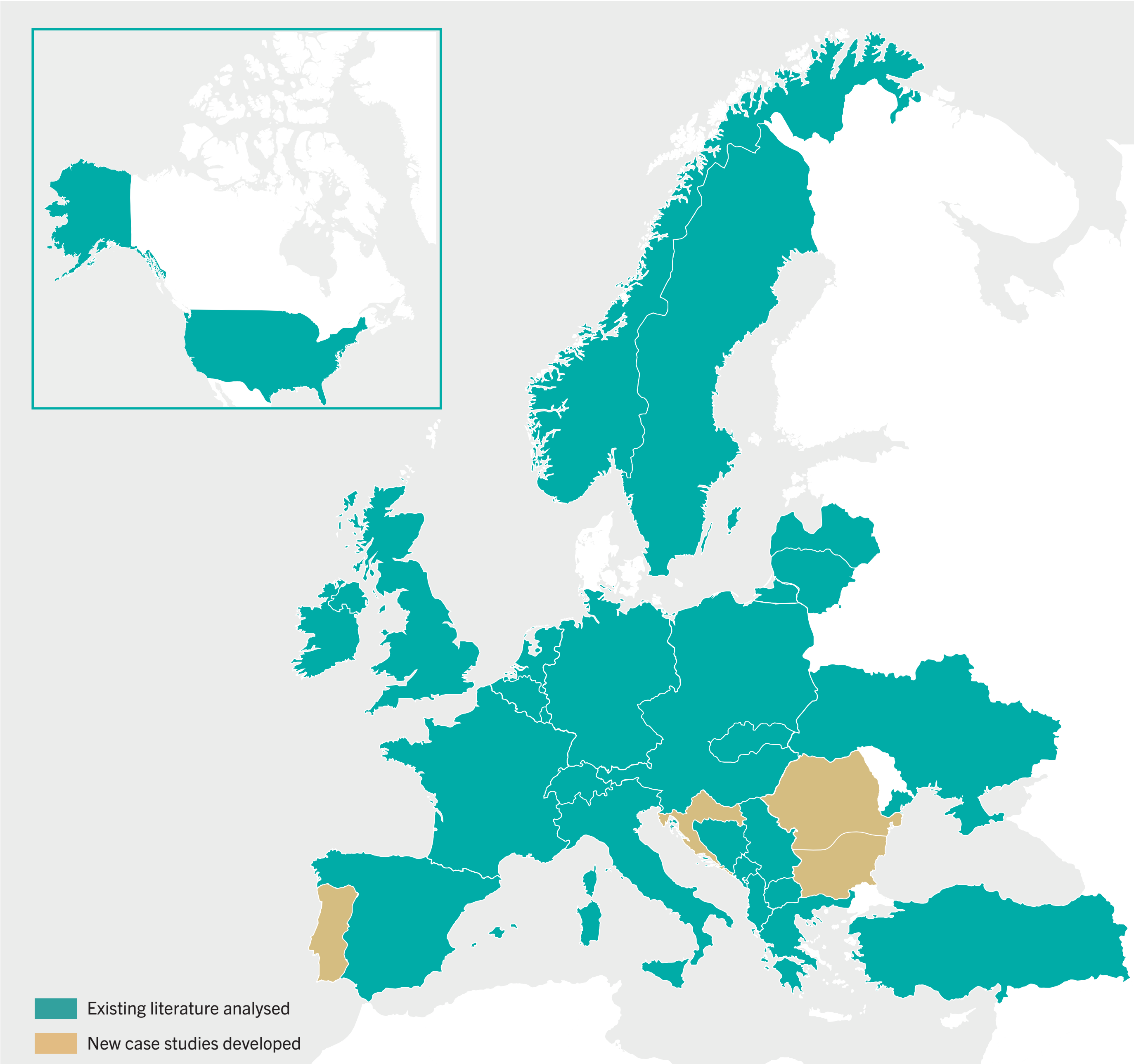
5. **Ready2Response (R2R) approach** focusing on multi-hazard preparedness and response at the national and local levels (Croatia).

**The selection of these case studies was also influenced by available data/ability to generate needed data and information, expert consultations, and consultations with counterparts**. Figure 8 show-cases the coverage of countries through existing and case studies.

**While drawing generic lessons from a set of case studies provides valuable insights, there are some limitations associated with this approach.** The first is publication bias which refers to the possibility that studies with statistically significant or interesting findings are more likely to be published. Second, the quality of individual case studies and available data may vary. Lastly, meta-analyses of case studies and national experiences may provide insights into specific situations, but general recommendations must always be adapted to the local context.

**As part of background research, a rapid overview of key funding sources available to the EU and UCPM PSs was conducted** focusing on resources available under the EU's MFF for ex ante (prevention, risk reduction, preparedness) and ex post interventions (response and recovery), with examples of countries targeting/using such funds.

**Figure 8.** Map showing case studies/examples considered




*Source:* World Bank.

# 1. Spotlighting the Exposure of Critical Emergency Infrastructure

**This chapter summarizes the results of the multi-hazard EU-wide exposure analysis for selected natural hazards.** Sectoral assets considered in this chapter as important for emergency response include fire and police stations, schools and hospitals, and roads and power lines. Hazards considered include wildfire, floods, earthquake, and landslide. The methodology for the EU-wide exposure analysis is described in short in the previous chapter with further details in Annex 1.

## KEY TAKEAWAYS

- **EU-wide exposure analysis shows that critical sectors' assets in Europe are exposed to a range of natural hazards in Europe.** This includes buildings providing emergency services, such as fire stations; associated buildings like police stations, schools (that are dual purpose shelters), and hospital (medical care); and road and power lines. It is also important to consider these facilities as critical infrastructure as they play a major role in the prevention, preparedness, response, and recovery processes.
- **Multiple hazards.** EU-wide exposure analysis shows that emergency response-related assets in Europe are exposed to a range of natural hazards in Europe. **In half of EU MSs', fire stations are located in areas exposed to high levels of wildfire, landslide, flood, or earthquake.** About 2,300 fire stations are exposed to high levels of two of those hazards, and 170 fire stations are exposed to high levels of three or all of the analyzed hazards. Cyprus (15 percent), Greece (8 percent,) and Croatia (5 percent) have the highest proportion of fire stations exposed to three of the analyzed hazards classified as high.
- **Wildfire: Across the EU, 32 percent or over 52,000 emergency response-related assets (fire and police stations, schools, and hospital) are in areas of high wildfire hazard.** About ten percent or 17,000 are in areas with very high hazard. For five EU MSs (Germany 14,700, Spain 8,500, France 12,800, Italy 8,300, and Poland 8,500), this amounts to over 8,000 assets each, and for many other MSs this means hundreds to thousands of emergency response-related assets exposed to high wildfire hazard. Four EU MSs have over 70 percent of these buildings exposed to very high and/or high wildfire risk—Spain 74 percent, Croatia 73 percent, Hungary 77 percent, and Portugal 80 percent. Similarly, five EU MSs have over 90 percent of roads and over 90 percent of power lines exposed (Portugal, Hungary, Spain, Greece, and Croatia).

- **Floods:** Across the EU, almost 3,500 fire and police stations, schools, and hospitals are already exposed to 10-year return period flooding which by no means is a rare event. Without appropriate flood protection and mitigation, this could severely affect emergency response and general service provision for education and health care causing ongoing recovery/repair costs.
- **Earthquake:** Eight EU MSs have over 35 percent of their fire and police stations, schools, and hospitals exposed to potentially damaging seismic hazard, ranging from a few hundreds to 2,000 in several countries and up to 9,000 in Italy. Given that many of these buildings predate modern seismic standards, they may be highly vulnerable. *There is very high exposure (up to 88 percent) of fire and police stations to at least strong seismic shaking in four MSs.*
- **Landslides:** Eleven MSs have hundreds of assets in areas of high landslide susceptibility, and several have thousands of assets exposed. *In Austria, Greece, Ireland, Portugal, Slovenia, and Spain, more than 80 percent of roads are in areas of high and very high landslide susceptibility,* while in Bulgaria, Greece, Slovenia, and Spain, 70 percent or more of power lines are in areas of high and very high landslide susceptibility.

## Understanding the Exposure of Critical Emergency Infrastructure

**Resilient critical infrastructures—including fire and police stations, health and education facilities, and transport, telecommunications, and power lines—are lifelines[41] essential for effective response and relief.** Emergency response-related infrastructure is often interconnected and failures in one sector can lead to cascading effects across others. Its design must therefore withstand shocks and disruptions, help reduce the overall impact of disasters on society, and contribute to the long-term sustainability of communities and nations.

**The location of CP infrastructure is important and relies on strategic planning and coordination to ensure that emergency response facilities are optimally situated to protect and serve their communities.** It is logical to locate emergency response assets in (or close to) high-hazard areas and populated areas, where impacts are most likely to occur or be most severe, to minimize the time required to respond to impacts and reports of casualties. This analysis does not assess the benefit of co-locating response assets in areas of potential damage, that is, shorter response time versus higher potential for damage, but acknowledges its importance in policy and investment decisions regarding siting emergency response assets. Accepting that the primary goal of siting emergency response assets is to maximize the effectiveness of the response, and being close to potentially affected communities and areas of high hazard is necessary, the emphasis of this analysis is on informing the necessary resilience of those assets (site-specific risk-informed designs, operational aspects, and so on) to perform their services when most needed.

**As part of this report, exposure maps have been generated at the EU level showing critical emergency assets exposed to high levels of multiple hazards.** Before this study, a comprehensive exposure mapping of critical infrastructure and CP assets in Europe was not available, at least not in an EU-wide consistent format. The advantage of this type of format is the comparability of information and identification of hotspots, which subsequently facilitates cooperation on CP and DRM and prioritization of investments. Generated maps provide an overview of the number and proportion of assets (fire, police, education, health, roads, and power supply) that are exposed to high hazards (wildfire, flood, landslide, and earthquake) based on publicly available and EU-wide consistent hazard and asset

41 Hallegatte, Rentschler, and Rozenberg. 2019.

data. These maps are useful for identifying across the EU, which can be prioritized for more detailed analysis to assess the benefits of investing in structural protection, location of new assets in lower-hazard areas, or other resilience measures. By focusing on these priority areas, decision-makers can develop effective strategies to manage the highest risk and minimize potential losses.

## Exposure to Multiple Hazards

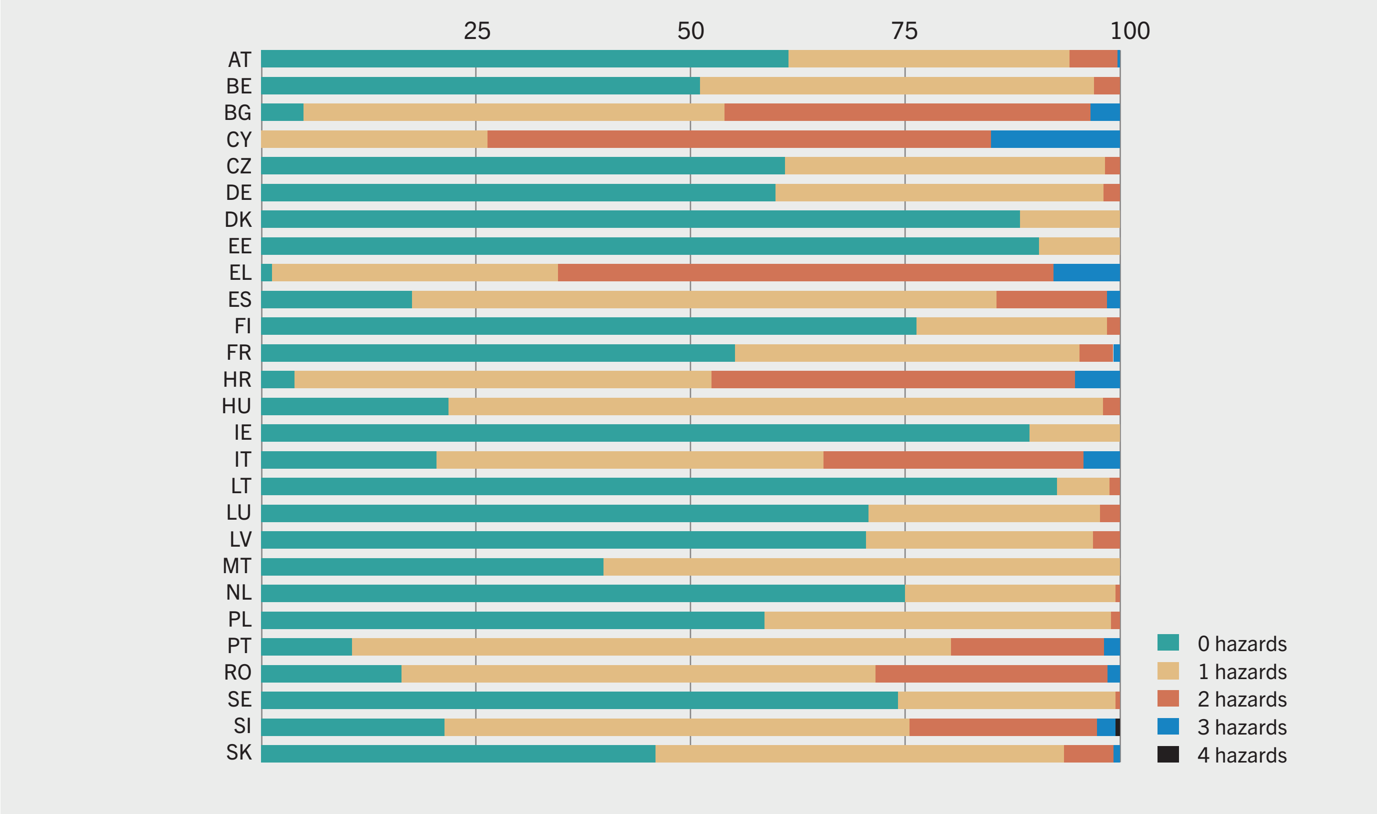
**Understanding the exposure of emergency response-related assets to multiple hazards is important for knowing the range of asset-level resilience requirements that may be needed at those assets, if any of those hazards materialize in isolation or in combination.** Concurrent and cascading hazards may include, but are not limited to, earthquakes triggering landslides or flooding and landslide occurring together. Just one of those hazards occurring at or near the asset could disrupt the response capabilities of first responders, or potential for the asset to be used as shelter, in the case of schools. While acknowledging the limitations of the EU-wide scale hazard data used in this exposure assessment, and lack of information around asset-level protection features and standards (see Terminology and Methodology section), the identified hotspots of multi-hazard exposure highlight concentrations of emergency response-related assets, on which attention should be focused to ensure multi-hazard resilience of CP.

**It is positive that a relatively small number of fire and police stations overall across the EU are exposed to multiple hazards, but in certain MSs, there is a high proportion exposed.** A total of 2,300 fire stations in the EU are exposed to two of the analyzed hazards, representing only four percent overall. Across all EU MSs, just over 660 police stations are exposed to high levels of three or all four of the analyzed hazards. A large majority of police stations are exposed to high levels of one hazard or none, and only 16 percent are exposed to two or three hazards.

**At the individual MS level, however, a different picture emerges—in some MSs most assets can be exposed to multiple hazards.** Cyprus has 59 percent of fire stations exposed to two hazards rated high, followed by Greece (58 percent), Croatia (43 percent), and Bulgaria (43 percent). Around 170 are exposed to high levels of three or all of the analyzed hazards, with Cyprus (15 percent), Greece (8 percent), and Croatia (5 percent) having the highest proportion of fire stations exposed to high levels of three of the analyzed hazards (Figure 9). Italy has the highest proportion (10 percent) and number (557) of police stations exposed to high levels of three analyzed hazards and another 35 percent (1,911 stations) exposed to two hazards. In Cyprus, 71 percent of police are exposed to high levels of two hazards, and six percent are exposed to three hazards. Greece (65 percent), Bulgaria (47 percent), and Croatia (46 percent) also have high exposure of police stations to high levels of two or three hazards (Figure 10).

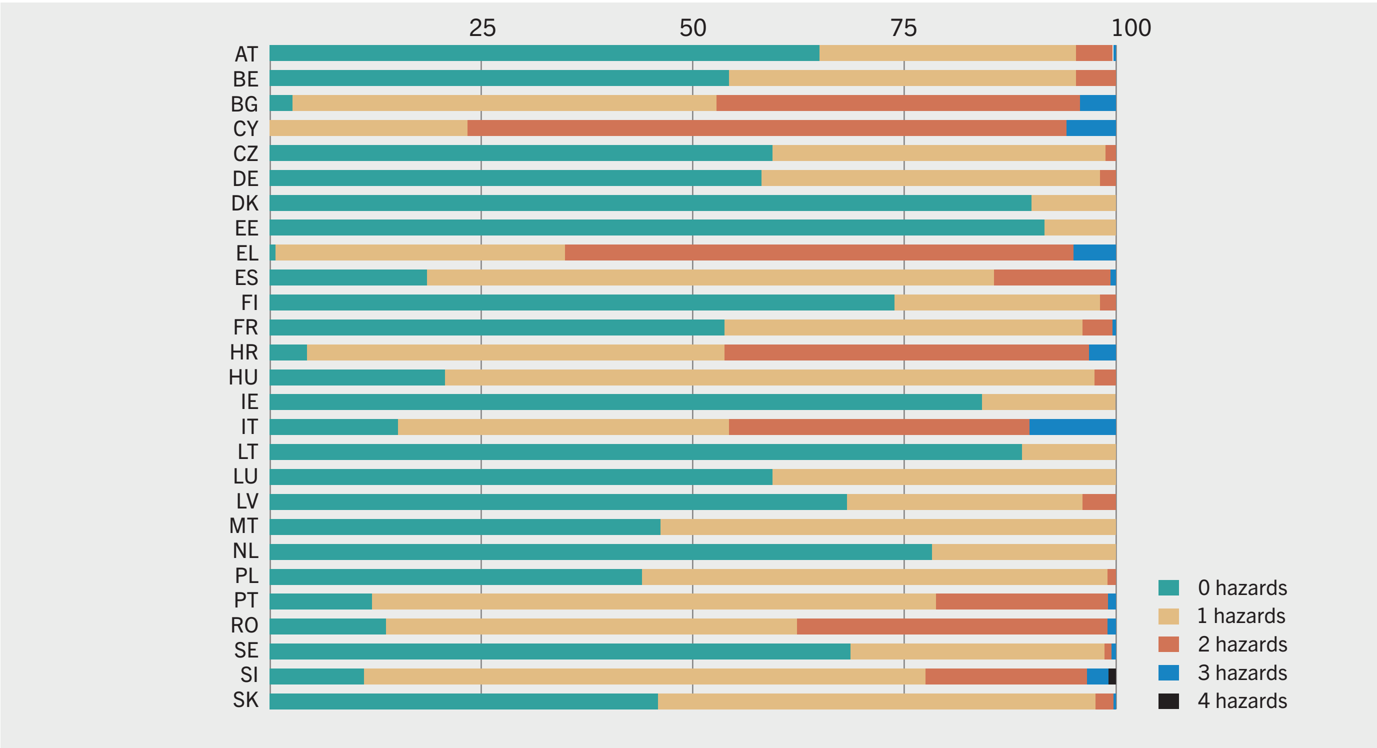
**This is of course not the case across the whole of the EU and there are MSs where exposure to multiple hazards is very low.** For example, the lowest exposure of fire stations is in Lithuania (93 percent exposed to none of the analyzed hazards), Estonia (91 percent), Ireland (90 percent), and Denmark (89 percent), with a similar pattern for police stations (Figure 10) and for educational and health care facilities reflecting the fact that the analyzed hazards are lower in these MSs. Having said that, there are also hazards that have not been included in great detail in this report such as strong winds/storms which are still relevant.

## **Figure 9.** Proportion of fire stations exposed to high levels of multiple hazards




*Source:* World Bank.

## **Figure 10.** Proportion of police stations exposed to high levels of multiple hazards

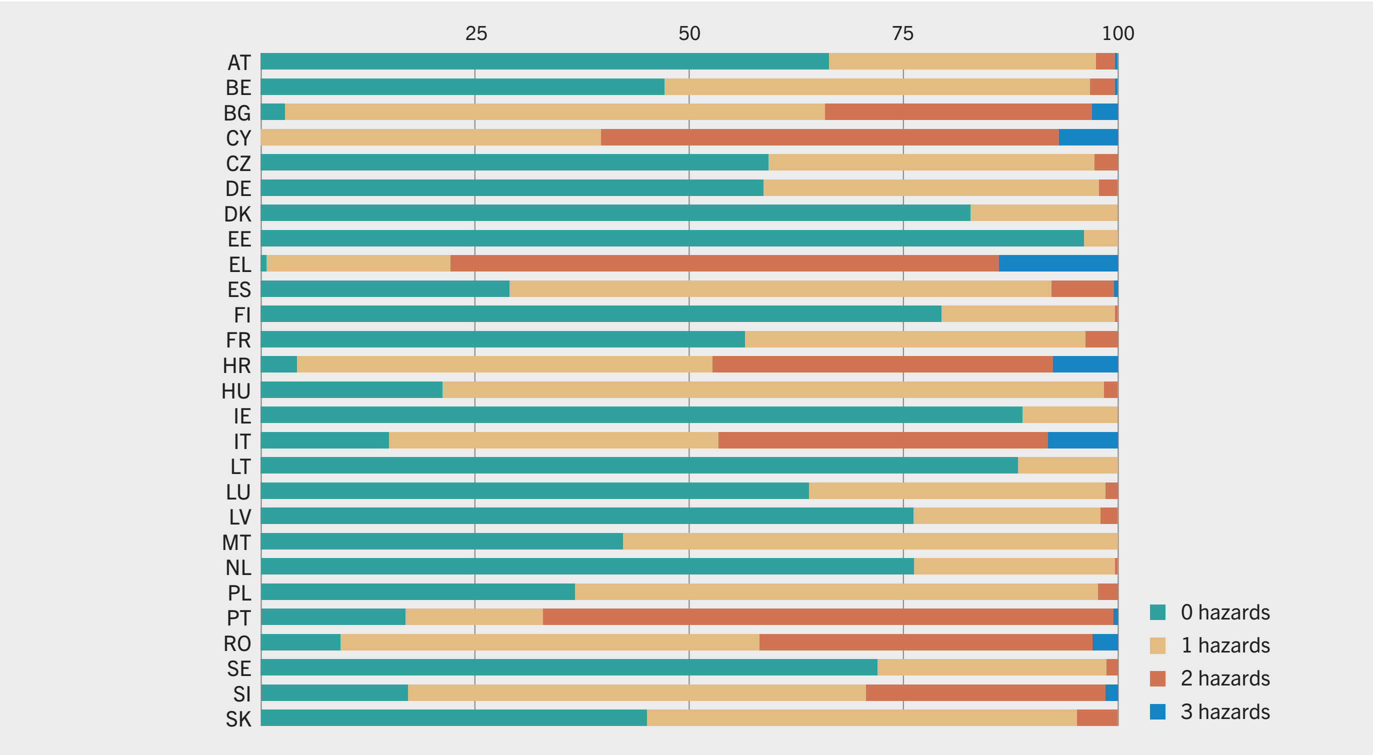



*Source:* World Bank.

**Fewer educational facilities are exposed to high levels of multiple hazards; almost one-third (30 percent) are exposed to one hazard classified as high.** About 36 percent are exposed to two hazards overall, and 1 percent (over 1,200 education facilities) are exposed to high levels of three out of the four analyzed hazards. A further 33 percent in the EU are not exposed to any hazards defined in this analysis. At the MS level, Greece (14 percent), Croatia and Italy (each eight percent) have the highest proportions of education facilities exposed to three of the analyzed hazards classified as high here Figure 11). Over 50 percent of education facilities in Cyprus, Greece, and Portugal are exposed to two hazards.

**A similar pattern is seen for health care facilities, with 44 percent of the 21,500 health care facilities analyzed across the EU being exposed to one of the four hazards.** A further 43 percent in the EU are exposed to zero hazards at a high level defined in this analysis. This leaves 12 percent of health care facilities exposed to two hazards, and 2 percent (340) are exposed to three or all of the hazards. The countries with the greatest proportion of health care facilities to two or more hazards are Cyprus (74 percent), Greece (65 percent), Croatia (48 percent), and Bulgaria (46 percent).

**Figure 11.** Proportion of education facilities exposed to high levels of multiple hazards




*Source:* World Bank.

**Comparatively few roads and power lines are either exposed to high-level hazards or exposed to only one of those analyzed:** 38 percent of road segments and 34 percent of power line segments in the European-wide data set are exposed to high levels of *one* hazard considered (wildfire, earthquake, flood, and landslide). **The caveats noted in the above flood section also apply here, especially concerning the length of such linear segments.** About 20 percent of roads and 12 percent of power line segments are exposed to two of these hazards. Seven percent of road segments (1,200) and 3 percent of power line segments (10,000) are exposed to high levels of three or four hazards at some point of the segment.

**In contrast with the fire, police, education, and health care assets above, the peak exposure of roads occurs in Croatia and Slovenia where each has around 22–23 percent of segments exposed to four hazards.** Croatia has a further 27 percent exposed to three hazards. Spain and Greece both have 43 percent of road segments exposed to at least three of these hazards. In terms of power line exposure, both North Macedonia and Montenegro have around 45 percent of segments exposed to three hazards—the highest multi-hazard power line exposure proportionally.

**In conclusion, it is important to further study the resilience of emergency response-related assets to *multiple* hazards in the countries identified above.** The countries with the highest proportional multi-hazard exposure of the emergency response-related assets are Croatia, Greece, Cyprus, and Bulgaria. The compounding risk to those assets and the operation of the CP systems, which arises from being in areas that could be affected by multiple hazards, should be assessed by integrating higher-resolution hazard data and climate scenarios, information on asset-level protection and resilience measures, and protection of the surrounding area from the hazard, for instance, by flood defenses.

## Exposure to Individual Hazards

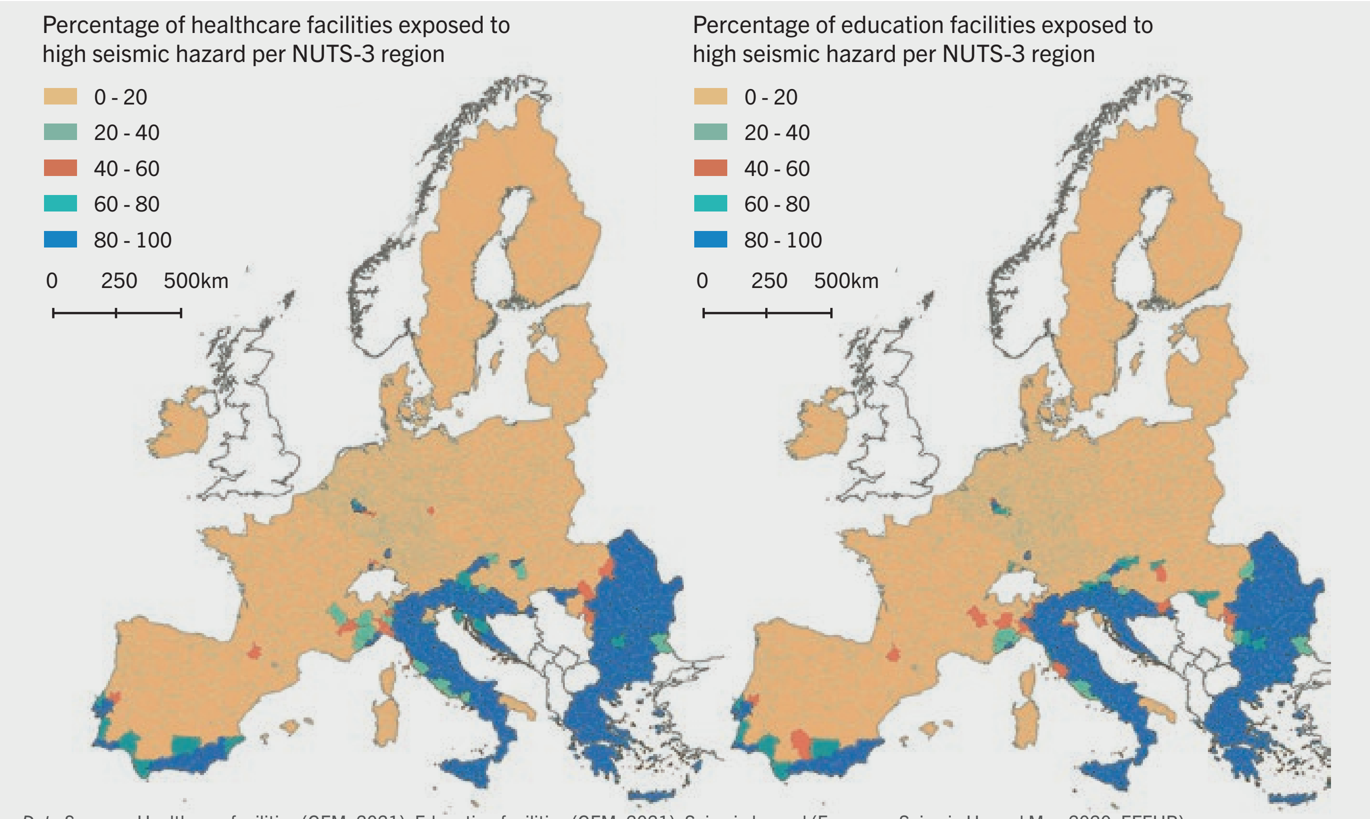
**The results of the exposure analysis show that countries typically associated with high wildfire hazard (for example, Greece, Italy, Portugal, and Spain) indeed have a high proportion (over 80 percent susceptible to very high wildfire risk) of emergency response-related assets** (education, health care, fire, police facilities) exposed to high wildfire hazard. The analysis suggests that across the EU, over 52,000 emergency response-related buildings (32 percent) are in areas classified in this analysis as high wildfire hazards and 17,000 (10 percent) as very high hazards. Spatial analysis conducted at the NUTS3 level shows that countries in eastern and southern Europe tend to have high exposure across most of their area while in central and northwest Europe exposure may be high in certain NUT-3 units but overall low national exposure. The results of this wildfire assessment are conservative, reflecting the location of buildings in *areas* susceptible to high wildfire rather than assessing that any individual asset may be damaged by wildfire (the resolution of the data does not support the latter).

**Furthermore, the exposure analysis reveals that almost 3,500 emergency response-related assets are exposed to flooding of over half a meter in the 1-in-10-year river flood zone across all MSs.** The countries with the greatest exposure as a proportion of assets are Luxembourg (6 percent), the Netherlands (5 percent), Finland (4 percent), and Belgium (4 percent). In the Netherlands, 160 of the 235 assets exposed are education facilities. Among the countries with the lowest exposure to flood hazard are those with consistently high exposure to the other analyzed hazards, including Cyprus, Bulgaria, Portugal, and Greece. Such frequent 1-in-10-year floods would be expected to cause minimal damage in many areas of Europe, due to local standards of flood protection being set to protect against such events. Nevertheless, examining the exposure to frequent flooding does highlight those assets most exposed to recurrent floods, in cases where flood protection is not in place, where events exceed local protection standards, or where defenses fail.

**The results of the exposure analysis show that in some areas, over 90 percent of emergency response-related assets have a ten percent chance in 50 years of experiencing strong seismic shaking** which correlates to buildings sustaining damage (MMI ≥ VI; 1-in-475-year return period). In Greece, Cyprus, Bulgaria, and Croatia, 90–100 percent of emergency response-related assets are exposed to this level of seismic hazard. Even in countries with proportionally fewer assets exposed to seismic hazards, such as above 60 percent proportion of exposure in Romania and Italy, or below 40 percent, such as Portugal and Austria, thousands of assets (including over 1,000 educational facilities alone in Greece, Romania, and

Italy) are exposed to potentially damaging seismic hazards. This highlights the importance of seismic strengthening of education facilities in earthquake-prone countries, as education facilities play a crucial role in the local community and society by housing students and other vulnerable groups, serving educational purposes, and functioning as shelters or resource centers during emergencies. The distribution of exposure (Figure 12) generally reflects, as expected, the distribution of high-seismic hazard in southern Europe, but within this pattern there are variations in the proportion of facilities exposed, seen, for example, in Germany and southeast France.

**Figure 12.** Example maps showing concentrations of exposure to high seismic hazard, for health care (left) and education (right) facilities



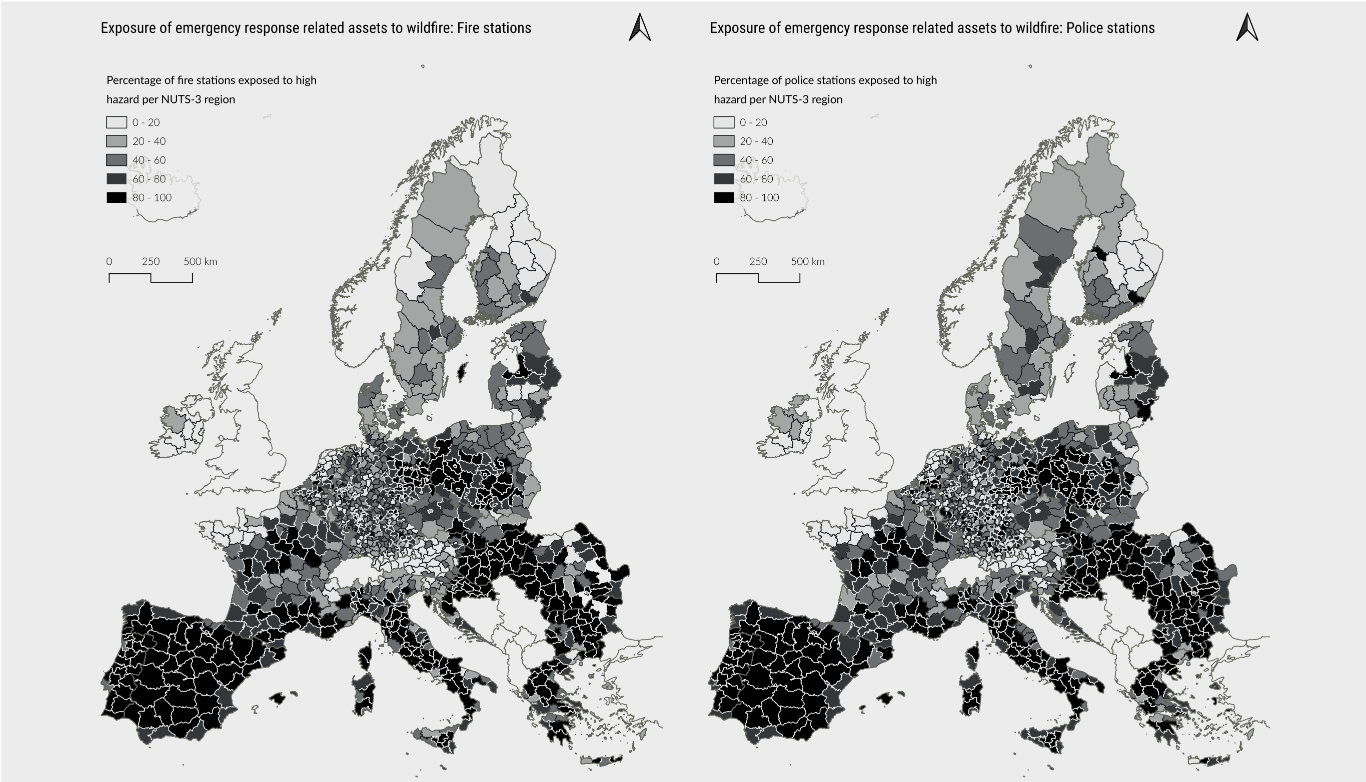

*Data Sources:* Healthcare facilities (GEM, 2021), Education facilities (GEM, 2021), Seismic hazard (European Seismic Hazard Map 2020, EFEHR), Administrative units (GISCO)

*Source:* World Bank.

**The seismic exposure analysis demonstrates well the sectoral nuances in exposure—not all sectors are equally exposed to the same hazard.** For instance, in Italy, though 67 percent of all assets are exposed to high seismic hazards, the percentage of fire facilities exposed is relatively low (49 percent). Meanwhile, in Slovenia, while overall 79 percent of all assets face high seismic susceptibility, the exposure level of police facilities is relatively high and reach almost 90 percent.

**Compared to seismic and wildfire hazard, there is relatively low exposure to high landslide susceptibility.** At the national level, the maximum exposure is 21 percent of all assets in Italy, but as Figure 13 shows, a very high proportion of exposure can be seen in individual NUTS3 regions. Only five EU MSs have over ten percent of emergency response-related assets exposed, and this is probably because landslide susceptibility is highly influenced by slope, and few such buildings are built in areas of steep slopes. However, even if buildings are not affected, if roads are cut off by post-earthquake landslides, for instance, then rescue and emergency response might still be hampered. To fully address the risk to assets in areas of high susceptibility, more detailed landslide run-out modeling would be required.

**Figure 13.** Example maps showing concentrations of exposure to high landslide hazards, for fire (left) and police (right) stations




*Source:* World Bank.

**Eleven countries have hundreds of assets in areas of high landslide susceptibility, and several have thousands of assets exposed—namely Italy, Austria, France, and Germany.** In France where only seven percent of all assets are in areas of high and very high landslide susceptibility, this translates to thousands of schools and hundreds of health care, fire, and police facilities. The asset type most exposed to landslide varies by country, demonstrating the need to understand and respond to sectoral differences exposure from country to country. This analysis indicates the number of assets that are in an area of high susceptibility, based on an EU-wide assessment. It does not consider property-level engineering, slope stabilization, and modifications, which may limit the occurrence of landslides and impact on the assets themselves.

## Results and Way Forward

**The results show that there is significant exposure of critical emergency assets to multiple hazards in some EU MSs, indicating the importance of multi-hazard approaches and the need to understand potential compound impacts.** In exposure hotspots where assets tend to be exposed to two, three, or four of the analyzed hazards, investments in the resilience of assets and emergency response activities should consider a multi-hazard approach and not address hazards individually. Such an assessment is also relevant for other critical infrastructure in other sectors to understand the impact across hazards and can be considered for the risk assessment planned under the CER Directive (2022/2557).

**The analysis also draws out sectoral nuances, for example, which sectors are most or dis-proportionately exposed, and informs further assessment of whether current investments are addressing the associated risk and resilience.**

For example, Italy, Greece, and Romania each have over 1,000 educational facilities exposed to high-seismic hazard, and all these countries already have in place programs addressing education infrastructure. Italy and Austria are, for example, countries with multiple of studies and efforts focusing on landslide risk, including specifically for the transport sector, while Portugal, Greece, and Spain are at the forefront of research and actions on wildfire prevention, which can provide important information to other countries which demonstrate pockets of exposure.

**By understanding the exposure of these assets to potential disasters, the EU can better prepare for emergencies and respond more effectively when they occur.** In case of a disaster event, understanding the susceptibility of emergency response assets can help CP authorities prioritize their efforts and allocate national and UCPM resources more effectively. Likewise, understanding the exposure of roads can also help prepare for disaster events to ensure adequate access. Furthermore, understanding the impact of various hazards on lifelines and critical functions, that is, the kilometers of power lines exposed to disaster, can support decision-makers to understand the susceptibility of the energy infrastructure, for example, for business continuity. Or, having information on exposure of roads to certain hazards is useful in preparing disaster response and avenues for effective response. Through understanding the exposure of emergency response assets, as well as transport and energy infrastructure, CP authorities are better equipped to protect lives and property in the event of a disaster.

**While thresholds used in exposure assessment can be considered subjective (the thresholds can be adjusted based on the purpose of the analysis or the assets of focus) and in some respects conservative, they are applied consistently across the EU MSs, enabling comparison within and between countries.** The results of this analysis can inform decision-making at the EU and national levels based on the locations, numbers of emergency response-related assets, and kilometers of critical infrastructure exposed. To refine the estimates presented here, further analysis must be undertaken to understand the sensitivity of results to using more refined high-resolution hazard information, different hazard intensity thresholds, and considering levels of protection using local knowledge and official information. The scope and focus of expanded analytics can then be linked and complemented by approaches mentioned in the next chapters. Investments in resilience should be underpinned by more localized analysis of individual assets and their local conditions, and the choice of further analysis can be informed by these EU-wide results.

**This analysis used a simplified EU-wide approach considering EU-scale data limitations.** Neither vulnerability information (data on construction attributes or asset-level protection) nor detailed information on flood protection or fuels with the potential to contribute to wildfire are available at this scale. Nonetheless, the quantitative exposure assessment can be used to inform future analysis, for example, to:

- *Invest in data analytics for critical infrastructure and response systems*, especially in areas with highest exposure to multiple natural hazards under current as well as future climate conditions, for example, South and East Europe.

- *Expand research in intensifying hazards due to climate change*, for example, probabilistic models for floods, wildfires, extreme temperature, and drought, noting the current gaps in granularity of data for some hazards such as wildfire and landslides.

- *Invest in data and analytics to be able to improve complexity of analysis*, including deterministic and probabilistic, systems thinking, and considerations of climate change.

- *Expand research to better understand compound risk*, including for specific sectors or groups of sectors.

- *Invest in analytics, planning, and investments for critical CP infrastructure* such as vulnerability of emergency response buildings and layers of analysis focusing on emergency response capacities, systems functionality, criticality, and so on.

# 2. Framework for smart investments in critical sectors

**This chapter summarizes the overall theoretical framework for prioritizing focused and smart prevention and preparedness policies and investments in critical sectors.** Following a short introduction, the chapter describes the key stages in the decision-making process, key steps in developing and using a prioritization framework, key elements within such a framework, and key analytical tools that can help integrate these elements and accompanying criteria and guide policy makers and practitioners in developing and using prioritization frameworks. A short fictional example at the end of this chapter helps move from theory to practice, with real-life examples and case studies provided in Chapters 3 and 4.

## KEY TAKEAWAYS

- **Given substantial needs and limited resources, prioritization of policies and investments is indispensable process to identify focused and smart—impactful, targeted, cost-effective, and sustainable—improvements in critical sectors. Prioritization is highly relevant for strategic planning (national or subnational level) and investment** planning related to critical sectors, areas or types of assets or investments, whether at the program or project level.
- **Prioritization is part of a broader decision-making process which varies depending on the local context and specific objectives.** This process generally includes key stages: (1) problem identification and goal setting, (2) baseline and sector analysis, (3) development and use of a prioritization framework, and (4) implementation and monitoring, and evaluation (M&E).
- **Within this four-stage decision-making process, the development and use of a prioritization framework (stage 3) follows separate steps.** These generally include (a) identification of assessment criteria, (b) assessment weighting of investment options based on the criteria, (c) ranking or scoring of options, (d) refinement of prioritization results with expert feedback and additional analysis, and (e) development of an investment action plan or roadmap and its implementation.
- **When developing and using a prioritization framework, several key elements need to be considered.** They include (a) the governance and strategic frameworks; (b) disaster and climate risk information; (c) financial, economic, environmental, and social aspects; and (d) context-specific factors which play a vital role in determining the prioritization and must be tailored to the unique geographic, climatic, economic, and social conditions of a region or a city. Recognizing that what works in one setting may not apply elsewhere is crucial for crafting effective prioritization processes and frameworks that address the particular vulnerabilities and challenges of each area.

- **Several prioritization tools and approaches are available and relevant for investments in critical sectors. Depending on their complexity, they address and respond to these key elements and criteria, data, and information.** This report focuses on seven such analytical tools: MCA, BCA, TDR, portfolio-based approach, critical analysis, performance-based approach, and the R2R framework. Many of these can be used in a complementary manner.
- **Data gaps should not be an excuse to delay urgent actions.** While all approaches require a certain level of data and information, even in the context of data limitations there are ways to use the prioritization tools in a rapid manner and/or build on the initial analysis systematically.
- **While prioritization depends on the specific context and there are many elements to consider, given existing knowledge gaps, when using analytical tools, policy makers and practitioners should aim to** (a) integrate disaster risk information and—as much as possible—future climate projections; (b) consider the criticality of networks/services or portfolio of emergency response-related assets; and (c) estimate benefits and costs of investing in prevention and preparedness.

## Prioritizing Investments in Resilience

**Preventive investments in resilient infrastructure make clear economic sense, deliver multiple benefits by protecting lives and assets, avoid disruption in critical sectors, and result in various developmental co-benefits.**[42] The analysis of over 70 case studies showed that the financial benefit almost always exceeded the cost (benefit-cost ratio [BCR]). Benefits were typically between two and ten times the cost and in some cases exceeded even twenty times,[43] highlighting the importance of investing in prevention and preparedness. For example, heatwave early warnings were found to provide significant benefits, with a mean BCR of 131 (range of 48–246).[44] Measures focused on wildfire prevention, such as managing wildland-urban interface (WUI), were found to have BCRs of 2.1 to 3.1; addition of fuel breaks in forested areas had a BCR of 12. Decision support tools for CCA and alerting for wildfire risk reduction yielded BCRs ranging from 5.8 to 39.[45]

**In Europe, the poor lose disproportionally more when hit by a disaster.**[46] Strategic thinking around investments in disaster resilience depends therefore—among others—on the mandate and perceived needs of different stakeholder group(s). Private business owners, for instance, make specific decisions to invest in the protection of their assets or functions to ensure business continuity. Households and individuals also make specific choices when they decide to purchase generators or prepare a basic disaster supplies kit. In both cases, private DRM investments are generally based on immediate needs and personal awareness/perception of local exposure and vulnerability (for example, floods versus extreme heat). A description of the different types of DRM investments is included in Annex 2.

42 ODI and World Bank 2015.
43 The BCR is a ratio to summarize results from a benefit-cost analysis (BCA), a process used to identify, measure, and analyze the benefits of a project, program, or decision versus the costs associated with it. The ratio summarizes the relationship between benefits and costs and net benefits are positive when the ratio is higher than 1.
44 World Bank and European Commission 2021b.
45 World Bank and European Commission 2021b.
46 Kerblat et al. 2022.

**High-quality data, tools, and technologies are important for prioritization to make smart decisions and provide the necessary insights to identify opportunities, assess risks, and allocate resources wisely.** For public institutions, prioritizing investments in disaster and climate resilience in critical sectors can be a complex task given resource limitations as well as conflicting priorities. The process demands a conducive institutional, political, regulatory, and financial environment that permits the efficient allocation of resources and clear definition of roles and distribution of responsibilities among relevant stakeholders.[47] Prioritizing actions/measures/investments often follows well-established processes for government planning and takes place at different governance levels focusing on the types of investments. Strategic goals and priorities are usually defined in national development plans and DRM/CCA strategies and often highlight specific policies and measures that should be pursued. Also, within critical sectors, sometimes specific locations or type of assets or interventions are given preference and dedicated funding (that is, multi-hazard, hazard-specific, or structural/nonstructural, infrastructure or social resilience related).

**Decision-makers must therefore prioritize those policies and investments that are *focused* on critical sectors and maximize the impact of available funds.** As noted earlier in this report, global research shows that prioritizing exposed infrastructure assets is cost-efficient.[48] But, beyond simple cost-efficiency, prioritizing investments for critical sectors can bring many additional benefits to a country and ultimately beneficiaries. First, prioritization can help ensure alignment with strategies at the national or EU level. Second, prioritization processes and frameworks can make better-informed decisions for disaster and climate resilience investments which maximize impacts. Third, the prioritization process can help decision-makers and stakeholders understand the overall process, specific considerations (for example, governance, geographic, socioeconomic, and environmental), and analytical approaches that can support decisions. This in turn can support broader capacity-building and institutional strengthening efforts related to disaster and climate resilience.

## Decision-Making Process including Steps to Develop and Use a Prioritization Framework

**Prioritizing investments is a systematic approach that helps decision-makers allocate scarce resources and determine the order of importance for considered interventions.** In the context of critical sectors, the decision-making process depends on the local context and specific objectives and needs and comprises four key stages, as illustrated in Figure 14: (1) problem identification and goal setting, (2) baseline and sector analysis, (3) development and use of a prioritization framework, and (4) implementation and M&E.

47 Bello, O., A. Bustamante, and P. Pizarro. 2021. *Planning for Disaster Risk Reduction within the Framework of the 2030 Agenda for Sustainable Development.* Santiago: United Nations. Link.

48 Hallegatte, Rentschler, and Rozenberg 2019.

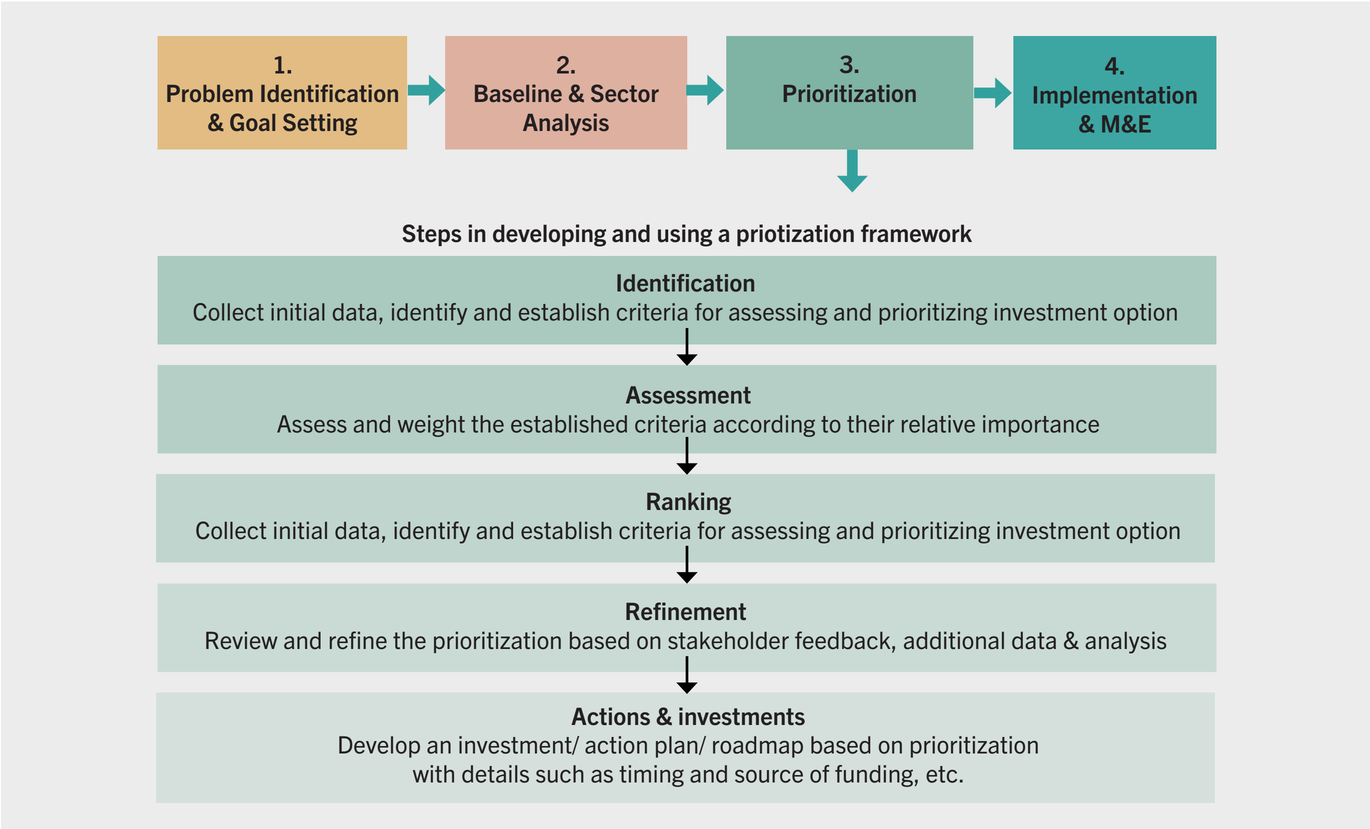
**Figure 14.** General decision-making process for investing in critical sectors

| | |
| --- | --- |
| **1. Problem Identification & Goal Setting** | • Problem definition<br>• Goals/key parameters setting |
| **2. Baseline & Sector Analysis** | • Risk/climate assessments<br>• Review/assess past/existing/planned DRM (or other sector-specific) measures<br>• Identify gaps and identify possible actions/measures to be analyzed and prioritized |
| **3. Prioritization** | • Identify appropriate methodology/approach<br>• Assess, evaluate/weigh, and prioritize different options<br>• Refine/consult results with stakeholders<br>• Develop policy roadmaps or investment plans |
| **4. Implementation & M&E** | • Implement prioritized investment options<br>• Monitor and review the implementation of projects<br>• Conduct impact evaluation and disseminate results |

*Source:* World Bank.

**Within this general decision-making process, at Stage 3, the development and use a prioritization framework follows a series of specific steps.** These include (a) identification of assessment criteria, (b) assessment weighting of investment options based on the criteria, (c) ranking or scoring of options, (d) refinement of prioritization results with expert feedback and additional analysis, and (e) development of an investment action plan or roadmap and implementation, as noted in Figure 15. In practice, these steps may differ depending on the various elements considered within a prioritization framework and analytical tools applied, as explained in the next sections. Also, likely, each of these steps requires further research, analytics, and technical and expert input, which is dependent on the local context and the complexity of the situation at hand. Beyond the specific context of a given measure/set of measures, developing a prioritization framework for investments is also heavily dependent on the availability or lack of data on risk and climate analysis and other aspects, such as the ability to consider functional or socioeconomic aspects. Abundant data environments enable more complex frameworks, while data-limited settings need to rely on simple/rapid data collection, simplified or phased approaches, or the use of proxies.

**Figure 15.** Steps in the development and using of prioritization frameworks




*Source:* World Bank.

**Once the prioritization framework is developed and a decision about prioritized policies or investments is taken, the implementation of chosen actions can begin (that is, Stage 4 of the decision-making process).** In this regard, M&E plays a crucial role in ensuring that DRM interventions are effective, efficient, and aligned with wider national or global objectives. An effective DRM prioritization frameworkrequires an effective M&E system comprising clear objectives, robust data management, stakeholder engagement, adaptability, and the ability to assess impacts and take adaptation measures based on real-time observations. According to a recent survey, only half of the EU MSs are currently deploying a methodology or indicators to monitor progress in the implementation of DRM planning decisions.[49]

An effective M&E system is built on several key pillars.[50] First, it requires clear objectives and indicators aligned with the goals of the DRM prioritization framework, ensuring measurable success criteria. Robust data collection and management systems, covering both quantitative and qualitative aspects of disaster risks and interventions, are essential. Baseline data are crucial for comparing pre- and post-implementation situations. Regular monitoring, involving all stakeholders, is vital for tracking progress. Stakeholder engagement, including government agencies, communities, civil society groups, and international organizations, ensures that diverse perspectives are considered. The system should furthermore be adaptable to changing circumstances, with a well-defined reporting mechanism to communicate progress transparently. A feedback loop allows stakeholders to contribute to improvements, and the integration of technology can enhance efficiency throughout the M&E process.

49 Spanish Presidency of the EU Council. 2023. Survey of the Spanish Presidency of the EU Council on Strengthening Governance for DRM in Europe: Systems, Strategies and Action Plans.

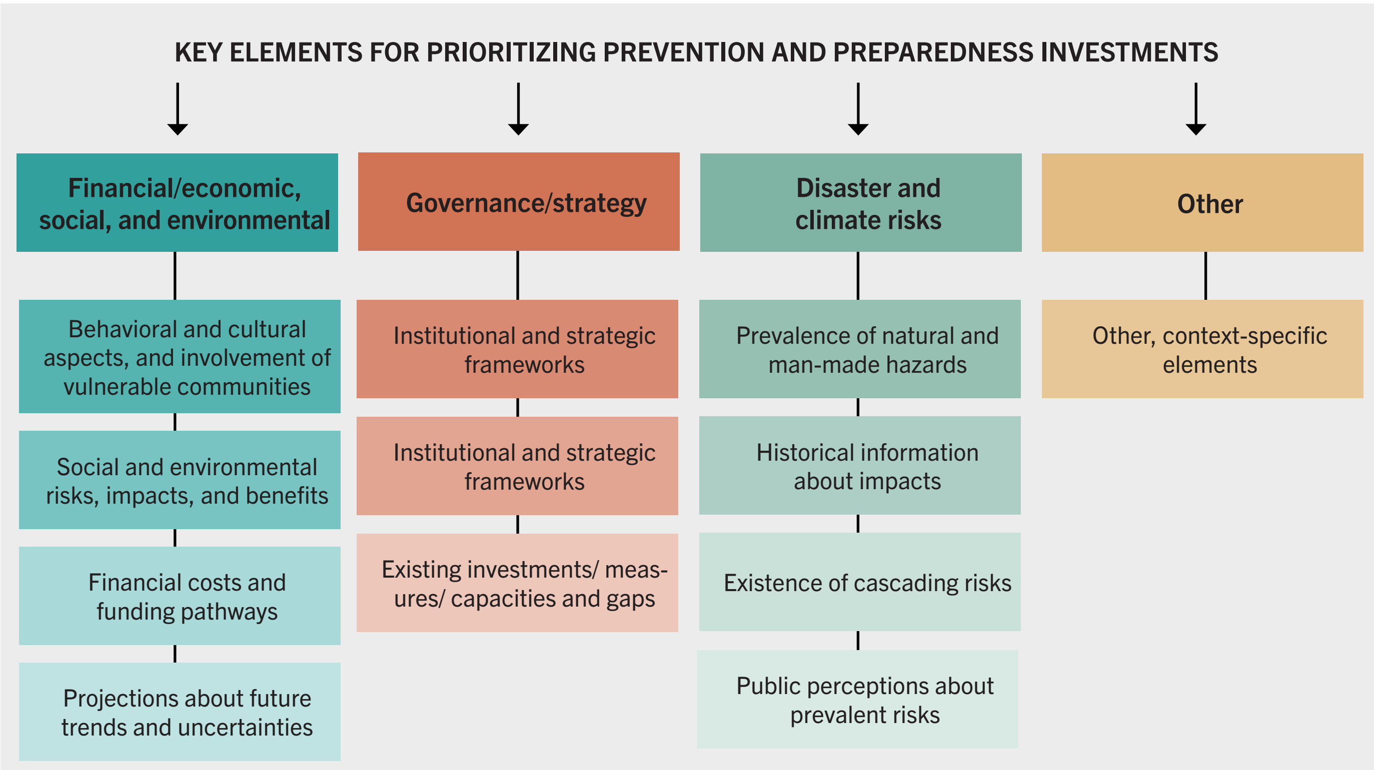
50 World Bank. 2017a. *Operational Guidance for Monitoring and Evaluation (M&E) in Climate and Disaster Resilience-Building Operations.* Link.; Scott et al. 2016. "Monitoring and Evaluating Disaster Risk Management Capacity." *Disaster Prevention and Management* 25 (3): 412–422. Link.; National Disaster Management Centre, South Africa. 2014. *Disaster Management Monitoring and Evaluation Framework.* Link.

## Key Elements of a Prioritization Framework

**As part of developing and using a prioritization framework, several key elements—or 'building blocks'—need to be considered.** These include considerations related to (a) the governance and strategic frameworks, (b) disaster and climate risk information, (c) financial, economic, environmental, and social aspects; and (d) context-specific factors. Figure 16 illustrates where these elements fit within the general decision-making process and prioritization framework, with examples under each element or 'building blocks'.

**Each element influences in its own way decisions about investments and interventions within the specific critical sector.** For instance, a prioritization solely based on risks may miss important social or economic dimensions. This is why a well-functioning prioritization framework consists of several or all of these elements. Depending on the overarching goals, priorities, available resources, engagement of relevant stakeholders, and the expected level of complexity, the prioritization framework may go into depth about these elements and/or may treat them in a rapid/simplified manner. The key elements are also closely linked to analytical tools which facilitate the actual analysis.

**Figure 16.** Elements or 'building blocks' to consider within a prioritization framework




*Source:* World Bank.

The individual elements are summarized below, with Annex 2 providing further information.

## GOVERNANCE-RELATED ASPECTS

**Global or regional frameworks provide general guidance to establishing strategies priorities.** The SFDRR, for instance, provides a global framework with seven targets, four strategic priorities, and eleven guiding principles and is intrinsically linked to the 2030 Agenda and Sustainable Development Goals (SDGs). This framework is commonly used by countries to provide a structure for national strategies which in turn guide subnational strategies, for example, in Romanian, where a draft National Disaster Risk Reduction Strategy is being finalized. At the EU level, the SFDRR and SDG agenda are further complemented by the EU's Action Plan on Climate as well as the EU's five DRGs which will inform priorities of EU MSs in the coming years. The goals set at the EU level foster a common understanding of the importance of disaster resilience and provide a platform for sharing best practices, exchanging knowledge, and promoting mutual learning among countries.

**Priorities at the EU level are then replicated through national DRM plans or strategies which guide national efforts in identifying, assessing, and managing risks associated with prevailing hazards.** Once strategic priorities have been identified, they are then reflected in national budget allocations and operationalized through dedicated programs. Greece, for instance, adopted the national Aegis program to upgrade and reform its CP sector,[51] and in the Netherlands, the government funds the Delta Works Program for flood risk reduction with structural and nonstructural measures as well as nature-based solutions (NBSs) to prevent the reoccurrence of major disasters like the ones in 1953 and early 1990s.[52]

### Disaster and climate-related aspects

**Decisions on DRM investments are generally grounded in an understanding of hazards, exposure, vulnerability, impact, and risk, but several methodologies and approaches can be considered.** Risk-based approaches may feed into more complex approaches (such as MCA) or are used to assess the likelihood of infrastructure failure or disruption (individual elements or whole system) due to natural or man-made hazards and the socioeconomic consequences of such failure/disruption. In practice, this approach can be applied on a portfolio of critical sector assets (for example, from Romania) or a network (criticality analysis)[53] and can include statistics, geographic information, satellite imagery, weather forecasts, artificial intelligence, and other innovative sources. Sound and reliable analytics identify patterns, trends, and risks which in turn enable the effective comparison and prioritization of available investment options. Prioritization across multiple hazards requires a deep understanding of risks being considered and their interrelationships/interdependencies. When appropriate, cascading effects are also considered, which is highly relevant for critical sectors and emergency situations.

**Prioritization of interventions in DRM must consider evolving risks with climate change, including average changes and likelihood of increasingly disruptive events.** Key advantages of risk-based approaches are the easy-to-understand and easy-to-communicate results,[54] the adaptability to different contexts and hazards, and the ability to take decisions based on solid evidence which enhances objectivity of the framework. The weaknesses of this approach are that risks are generally subject to uncertainty and incomplete or unreliable data can affect the overall reliability of results. Furthermore, risks are not static but can evolve over time due to various factors such

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51 'Aegis', the largest program ever designed to strengthen CP in Greece. The total budget of the project is €1.7 billion, of which €380 million comes from the Recovery Fund. Defence Exhibition Athens. 2022. *Civil Protection: Tenders 1.7 Billion for Helicopters, Firefighting Aircraft, Drones.* Link.

52 Government of the Netherlands. 2023. *Delta Programme: Flood Safety, Freshwater and Spatial Adaptation*. Link.

53 For further information about multisectoral and multi-hazard infrastructure network risk analysis, see Mahul et al. 2021. *Piloting the Next Generation Analytics for Climate-Related Financial Resilience of Critical Infrastructure in Southeast Asia.* Link.

54 For example, the risk communication tool RiskViewer for Latin America and the Caribbean. World Bank/GFDRR. LAC RiskViewer. Link.

as environmental changes, socioeconomic developments, technological advancements, and shifts in population patterns.[55] By focusing too much on the risks, there is also a chance that the perspectives and needs of local communities may be neglected.

**Risk-based approaches are generally highly data driven.** To better understand possible outcomes and their associated probabilities, probabilistic modeling is used in situations where uncertainty and variability play a significant role to assess the likelihood of various hazards occurring, their potential impacts, and the resulting risks. This approach provides decision-makers with a more comprehensive understanding of the range of possible scenarios and helps guide more informed choices. Risk prioritization indexes may be defined, employing a weighted summation of multiple considered attributes (for example, probability, impact, proximity, spatial context, uncertainty, manageability, and response effectiveness).[56] Weights should be clearly established to enhance transparency. Expert opinion is normally incorporated into the prioritization process.[57] At the EU level, risk information is, for example, available through the Index for Risk Management (INFORM), developed by the JRC.[58]

### Financial/economic, social, and environmental aspects

**When prioritizing DRM investments within critical sectors, financial and economic aspects naturally play a crucial role.** These aspects involve the consideration of financial resources and allocation, funding mechanisms and leveraging of additional resources, cost-effectiveness in decision-making, and financial/economic sustainability. Several methodologies are used for financial/economic analysis of DRR investments.[59] These may include the following: the TDR framework, BCA, rate of return (RoR), return on investment (RoI), and cost-effectiveness analysis (CEA). An example of a framework which considers different financial and economic elements is given in Box 4.

**BOX 4.** DEVELOPING A BUSINESS CASE FOR INVESTMENTS IN THE UNITED KINGDOM

The United Kingdom's Treasury provides guidance on how to conceptualize projects and business cases through a Five Case Model Methodology. This methodology comprises five key considerations: (a) the strategic case determines the need for change, its strategic fit, and rationale for intervention; (b) the economic case looks at the net value to society compared to continuing with business as usual; (c) the commercial case determines a well-structured 'ideal' between the public sector and its service providers; (d) the financial case demonstrates the affordability and funding of the preferred option; and (e) the management case ensures that viable arrangements are in place for the delivery, monitoring, and evaluation of bespoke project or investment.[60] This methodology is applicable to policies, strategies, and projects and investment programs.

55 Cremen et al. 2022. "Modelling and Quantifying Tomorrow's Risks from Natural Hazards." *Science of the Total Environment* 817. Link.
56 IPCC 2012; Poljanšek et al. 2017.
57 Ioannou et al. 2022. "Prioritization of Hazards for Risk and Resilience Management through Elicitation of Expert Judgement." *Natural Hazards* 112: 2773–2795. Link.
58 For more information about the INFORM index, see JRC. DRMKC - INFORM. Link.
59 World Bank and European Commission 2021a, 36.
60 UK HM Treasury. 2018. "Guide to Developing the Project Business Case - Better Business Cases: for Better Outcomes." London: Open Government License (OGL). Link.

**By considering environmental and social aspects, decision-makers can integrate additional considerations into risk reduction measures, ensuring a holistic and sustainable approach to DRM.** For example, one can prioritize DRM investments that promote environmental sustainability, social vulnerabilities, protect ecosystems, or promote community engagement and gender inclusivity. These aspects are however generally difficult to quantify.

### Other elements

Depending on the context, other elements may be relevant as well, for instance, sectoral or cross-sectoral issues, knowledge or information management, or technology and innovation aspects. See Annex 2 for a list of key trade-offs.

## Key Analytical Tools for Prioritization

**Several prioritization tools and approaches are available and relevant for investments in critical sectors.** Depending on their complexity, they address and respond to the key elements, selection criteria, data, and information. The selection of analytical tools should be guided by overarching goals, priorities, and available resources of the decision-making entity as well as the participation and engagement of relevant stakeholders. To increase robustness in decision-making and drawing meaningful conclusions besides sufficient information/data input, it is recommended to apply several complementary tools even though it may increase complexity. For instance, the classic benefit-cost analysis approach is greatly enhanced by a minimum input of risk information as well as potential socio-environmental co-benefits that could be realized because of the investment.[61]

**The most common prioritization tools for critical sectors are provided in Box 17 and their key strength and weaknesses are described in Table 1, with a more detailed summary presented below.** Besides these seven, there are also other prioritization tools which are detailed in Annex 2. When deciding which tool/approach may work best, practitioners would consider aspects such as (a) availability of data and information; (b) size and capacity of agency; (c) technical skills required; (d) financial resources needed; (e) ability to include participatory and inclusive approaches; and (f) overall flexibility of tools and the potential to integrate new data and information as it becomes available.

**BOX 5.** SUMMARY OF KEY RELEVANT APPROACHES

- **Multi-criteria analysis (MCA)** can identify priorities within strategies and investment plans across different levels of decision-makers. In recent years, it has been used by several EU MSs for developing national DRM plans. In Greece and Bulgaria, this approach made it possible to bring together different priorities across different hazards and sectors; the results informed the identification of subsequent programs, projects, and priorities, such as those under the countries' respective NRRPs.
- **Benefit-cost analysis (BCA)** focuses on monetizable benefits and costs linked to projects/investments to determine economic justification. It is widely applied in public policy decision-making, particularly for infrastructure. The Portugal case study used a comprehensive benefit-cost analysis to understand the potential benefits of the program.

61 Mechler, R. 2016. "Reviewing Estimates of the Economic Efficiency of Disaster Risk Management: Opportunities and Limitations of Using Risk-Based Cost–Benefit Analysis." *Natural Hazards* 81 (3). Link.

- **The Triple Dividend of Resilience (TDR) approach** expands the traditional BCA approach and considers three types of benefits: avoided losses when disasters strike, stimulated economic activities and innovation arising from reduced risks, and generated socioeconomic and environmental co-benefits. Whether for a portfolio of assets or individual programs/projects, investment decisions can be greatly enhanced by using a TDR approach; the Croatia case study applied this approach.

- **Portfolio-level assessments** can clarify the condition and risk levels of a portfolio of assets (such as fire stations, schools, or hospitals). Existing lessons learned from Romania and a new case study in Croatia show the potential of using this kind of analysis and associated results for prioritizing integrated investments in upgrading/reconstruction of CP and education buildings at high risk.

- **Criticality analysis** can improve the understanding of the resilience of networks—such as transport, energy, or health—and impacts of shocks within it. The Romania case study shows how information on flood risk and criticality can be used to better target investments.

- **Performance-based approaches** can complement different types of analysis by focusing on specific performance indicators. Bulgaria case study used a performance-based analysis to integrate considerations of heat and wildfire risks into the prioritization framework circumscribed by the national DRM plan.

- **The Ready2Respond (R2R) approach** can quickly yet systematically illuminate the key strengths and weaknesses of CP and emergency response systems by covering key capacities, namely (a) legal and institutional framework, (b) personnel, (c) facilities, (d) equipment, and (e) information. In the Croatia case study, the self-assessment was used to generate a rapid yet comprehensive overview of the strengths and weaknesses of the preparedness and response system at country and city levels.

**Table 1.** Strengths and weaknesses of key analytical tools

| ANALYTICAL TOOL | STRENGTHS | WEAKNESSES |
|---|---|---|
| **Multi-criteria assessment** | Comprehensive and transparent results. Flexibility (including weighting of criteria) allows adjustment to policy makers' needs. Inclusiveness can be assured through stakeholder consultations. | Potential complexity in determining criteria and assigning values. Dependence on the accuracy of expert evaluations. There are also challenges in handling uncertainty. |
| **Benefit-cost analysis** | Clear and objective economic justification for investments. | Potential limitation in capturing social, environmental, and broader DRM-related impacts that cannot be easily monetized, as well as climate uncertainty. |
| **TDR approach** | Reconciles perspectives from DRM, environmental, and economic fields. Provides a more comprehensive view of investment impacts. As a collaborative exercise, it captures potential positive and negative impacts qualitatively. | Restriction due to data limitations for calculating broader dividends (time-intensive data collection). There are challenges in quantifying broader socioeconomic and environmental impacts. |
| **Portfolio-based approach** | Allows a more strategic analysis of a pool/ portfolio of assets or activities. This allows to better understand how a whole network/ groups of assets perform. Can be done in a rapid manner and integrate new information gradually. | More detailed data are required for comprehensive portfolio prioritization. This approach cannot be used for determining asset-level specific solutions. |
| **Criticality analysis** | Incorporates various criteria, such as vulnerability and risk level. Applicable in data-limited environments, with potential for scalability. | Dependent on the availability of required data. May require extension as data availability and capacities increase. |

| ANALYTICAL TOOL | STRENGTHS | WEAKNESSES |
|---|---|---|
| **Performance-based approach** | Outcome oriented, providing clear understanding of potential impacts. Identifies gaps for additional investments. Aims to maximize impact and enhance overall disaster resilience. | Dependent on defining meaningful and measurable indicators. Requires careful assessment of the effectiveness of DRM measures. Risk that non-performance-based benefits may be overlooked. |
| **Ready2Respond** | Comprehensiveness - covering multiple criteria, indicators, and attributes. Flexible methodology. Data-driven and objective foundation. Can be done as self-assessment at different administrative levels or focusing on specific hazards or areas. | Resources required to manage the assessment, retention of results, as well as regularity of undertaking the assessments. Primary focus of the methodology is on preparedness and response. |

*Source:* World Bank.

**Prioritization tools may focus more heavily on specific elements or consider a range of elements as outlined earlier** (see also Figure 16). Also, tools have their own specificities and are applicable at different stages of the policy or investment preparation cycle. For example, disaster and climate risk-based approaches in combination with a comprehensive exposure/vulnerability assessment (at the appropriate level/scale) and analysis of climate scenarios could be a first step and contribute to the identification of gaps in DRM measures. Governance/strategy- and DRM-related approaches (like portfolio- or performance-based approaches) come into play once information about existing DRM measures and gaps has been gathered. Economic- and social-related approaches (for example, TDR or BCA) would also play a role at a certain stage of the prioritization process. Related to links between DRM and CCA, as generally models support projections further into the future, increasingly prioritization of interventions for CCA takes an iterative, step-by-step approach. It starts with identifying measures that can be implemented in a given time frame/phases that would work under several scenarios, have high co-benefits, are no-regret measures, can be adapted/adjusted as more information becomes available, and/or are rather cost-effective.

**Table 2.** Analytical tools and focus on specific elements ('building blocks')

| Elements / Tools | Governance/ strategy-related | Climate and disaster risks | Financial & economic | Social | Environmental | Useful for DRM |
|---|---|---|---|---|---|---|
| Multi-criteria analysis | X | X | X | X | X | X |
| Benefit-cost analysis | | (X) | X | | | X |
| Triple dividend of resilience | | X | X | X | X | X |
| Portfolio based | | X | X | | | X |
| Criticality analysis | | X | X | | | X |
| Performance based | | X | X | | | X |
| Ready2Respond | X | (X) | | | | X |

*Source:* World Bank.
*Note:* (X) = partial congruence of an approach with respective element.

### MULTI-CRITERIA ANALYSIS

**MCA is a commonly used approach to evaluate and select from various options or measures considering several criteria, which in turn can lead to varying prioritization outcomes.** It is a structured, yet flexible, tool allowing users to combine expert evaluations. The MCA identifies, weighs, and evaluates a set of qualitative and quantitative criteria, such as economic, social, environmental impacts or other factors, and aggregates the individual scores to make informed and transparent decisions. Criteria are typically assigned values to provide quantitative scores and enable comparison of alternatives. Weighting of criteria shows their relative importance. Within MCA, different analytical methods can be applied, including outranking (that is, Electre, Promethee), multi-attribute utility and value theories, and nonclassical approaches (that is, dealing with uncertainty).[62] The advantages of this approach are grounded in the comprehensiveness and transparency of results, and the weighing of criteria furthermore enhances objectivity. Another benefit is that MCA is flexible and can be adjusted to policy makers' needs at different administrative levels seeking to prioritize among measures. Furthermore, MCA usually includes stakeholder consultations, which makes this approach inclusive.

**Related to critical sectors and DRM investments, MCA is often applied at policy-level decision-making, including for national DRM strategies/ plans.** In general, the following steps are taken when MCA is applied to inform a national DRM strategy/ plan: determining the number, type, and definition of criteria; determining the relative weight of criteria significance; evaluating measures by assigning scores; evaluating measures against criteria based on the weighting method; and prioritizing measures (total score). Countries that used MCA for the development of National Disaster Risk Management Plans (NDRMPs) include **Bulgaria**, **France, Germany, Greece, the Netherlands**, **Portugal**, **Romania**, and **Türkiye.**[63]

**MCA analysis can also expand the traditional focus on direct damage to assets by integrating also estimated social welfare impacts and in this way inform investment priorities that can benefit the poor and vulnerable**.[64] Assessments centered on asset losses, tend to focus on investments in wealthier areas and fail to address the disproportionate impacts on poor households. In contrast, focusing on welfare impacts considers well-being losses and socioeconomic resilience, providing a more nuanced understanding of the broader impacts of disasters and their implications for poverty reduction and sustainable development. By integrating the socioeconomic context and distributional effects as part of its criteria, the MCA can guide DRM strategies and investments towards more inclusive and effective risk reduction interventions, aligning with the broader development agenda.

**Beyond evaluation of risk, an important consideration for the DRM sector is also the urgency for action.** This depends on the extent to which risks are already being managed and the capacity and coping mechanisms (including resilience) in place. It also relates to the urgency of action needed and the type of action, that is, whether there is a need for immediate direct action or a priority for further understanding of the risk. This can identify which actions are most critical and help in investment prioritization. For example, MCA frameworks can help DRM practitioners enumerate strategic investment options in their ability to accomplish predefined objectives and establish a structured procedure to prioritize these potential prevention initiatives.[65]

62 Figueira el al. 2016. *Multiple-Criteria Decision Analysis. State of the Art Surveys.* New York: Springer International Series in Operations Research and Management Science. Link.

63 Manyaga et al. 2020. "A Systematic Literature Review on Multi-Criteria Decision Making in Disaster Management." *IJBES* 2 (2). Link.

64 Kerblat et al. 2022.

65 da Silva, G.F.P., and M.C.N. Belderrain. 2019. "Prioritization of Strategic Initiatives in the Context of Natural hazard Prevention." *Brazilian Journal of Operations* & *Production Management* 16 (3): 473–489. Link.

### BENEFIT-COST ANALYSIS

**This methodology focuses generally on the immediate (direct/indirect) benefits that are linked to a project/investment and can be easily monetized (tangible values) and hence prioritized.** The BCA determines whether the benefits outweigh the costs and whether the investment is economically justified. This approach is widely used in public policy decision-making, especially for infrastructure investments. While the analysis is clear and objective, its reliance on monetary values may not capture all social and environmental impacts of the investment. Efforts have been made to use BCAs in a risk-based approach more adapted to the analysis of systematic, integrated, or soft investment.[66] **Japan**, for instance, uses BCA as a prioritization tool, but evaluates project efficiency three to five years after adoption.[67] The case study on **Portugal** combined a vulnerability/susceptibility analysis with a BCA (see Box 5 for a brief summary and Chapter 4 for more details).

**BOX 6.** PORTUGAL CASE STUDY: COMBINING VULNERABILITY AND BENEFIT-COST ANALYSES

The Portugal case study analysis employed a data-driven vulnerability approach, combining expert knowledge and geographic data analysis to prioritize villages based on various factors. It also conducted a comprehensive BCA to assess the program's economic viability under different scenarios. This methodology served as a robust framework for making informed decisions about resource allocation and wildfire risk reduction in Portuguese civil parishes.

### TRIPLE DIVIDEND OF RESILIENCE FRAMEWORK

**The TDR framework is a comprehensive approach that aims at estimating a variety of wider benefits of DRM investments that are typically overlooked, leading to a more balanced prioritization.** The approach assesses each DRM investment option by three possible types of benefits—or dividends of resilience—that those investments can yield (a) avoiding losses when disasters strike; (b) stimulating economic activities and innovations by reducing disaster risks; and (c) generating social, environmental, and economic co-benefits in the absence of disasters (see Figure 17). This TDR methodology was applied in a 2021 study by the World Bank and EU to analyze more than 70 investments ex ante and ex post.[68] For example, heatwave early warnings were found to provide significant benefits, with a mean BCR of 131 (range of 48–246). Measures focused on wildfire prevention, such as managing WUI, were found to have BCRs of 2.1 to 3.1; addition of fuel breaks in forested areas had a BCR of 12. Decision support tools for CCA and alerting for wildfire risk reduction yielded BCRs ranging from 5.8 to 39.

**The approach reconciles perspectives from the DRM, environmental, and economic fields, but sometimes it is restricted by data limitation and hence ability to calculate the broader dividends.**[69] This is usually more complicated for quantifying the broader socioeconomic and environmental impacts, with limited literature and practical analysis on this available. For example, it is crucial to have sufficient time for data collection and undertake baseline data collection for ex ante analysis and consult stakeholders for ex post analysis. As the selection of certain parameters or hazard scenarios can greatly affect the result, it is recommended to take sensitivity analysis and present a range of possible results. Also, a collaborative and consultative exercise should be undertaken to think through the potential impacts (positive and negative) of the investments. Even if the analysis may underestimate these impacts quantitatively, they should still be documented qualitatively.

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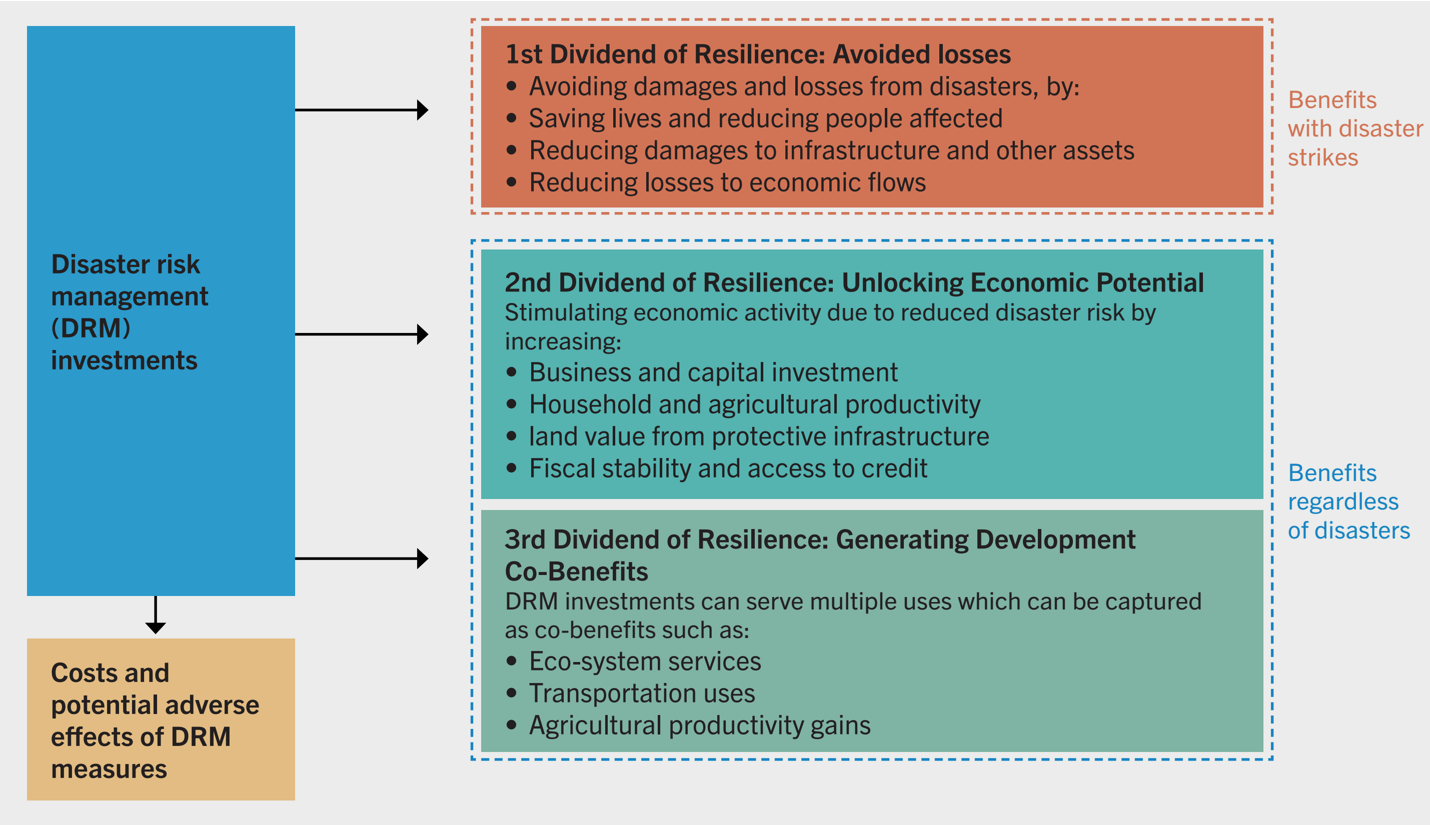
66 OECD. 2006. *Cost-Benefit Analysis and the Environment.* Paris, France: OECD. Link.
67 Ranghieri, F., and M. Ishiwatari. 2014. *Learning from Megadisasters: Lessons from the Great East Japan Earthquake*. Link.
68 ODI and World Bank 2015; as demonstrated by World Bank and European Commission (2021a).
69 ODI, GFDRR, and World Bank. 2015. *The Triple Dividend of Resilience*. Link.

**Figure 17.** Triple dividend of resilience




*Source:* ODI, GFDRR, and World Bank 2015.

**BOX 7.** CROATIA CASE STUDY: USING THE TDR FRAMEWORK

The Croatia case study presented in this report illustrates the use of sector-specific prioritization tools, focusing on CP as a critical sector. Based on collected data on the condition of the buildings, seismic risk analysis was used to understand the potential risk facing these buildings given their location and current condition. Combined with data on occupancy, energy efficiency, and other elements, the TDR framework was used to calculate benefits of avoided losses related to people and infrastructure and disruption, benefits related to energy efficiency and risk reduction, and costs related to upgrading/reconstruction to guide future decision-making toward prioritization of investments. This case shows that prioritization decisions can be informed through improved understanding of the assets at risk and opportunities when rehabilitating/replacing these with new buildings. This approach can be highly relevant to UCPM members with exposed/vulnerable CP infrastructure to disaster and climate risks.

## PORTFOLIO-BASED APPROACH

**The TDR framework can also be applied as part of the portfolio-based prioritization tool for investments in critical sectors which involves analyzing and selecting a set of investments or projects that collectively maximize the effectiveness and efficiency of resilience-building efforts.** It considers the interdependencies and synergies among different investments to create a balanced and coherent portfolio of initiatives. This approach ensures that resources are allocated strategically and optimally across a range of DRM activities. For example, in **Romania** and **Croatia**, a portfolio of CP infrastructure (buildings) has been analyzed based on prevailing risks and retrofitting/reconstruction costs. The result was a list of prioritized investments; details of these two cases are presented in the next section.

## CRITICALITY ANALYSIS

**Criticality analysis has been used in several contexts for the prioritization of infrastructure investments within critical sectors, often in combination with socioeconomic assessments.**[70] The criticality methodology is considered robust, scalable, and practical and based upon objective criteria to the extent possible. It often considers various criteria (such as vulnerability and risk level) and can be combined with other approaches to prioritize investments. It can be applied in environments where not all required data are readily available, or capacities are lower but can easily be extended in case data availability and capacities increase.

**Analysis of the vulnerability of segments against risk of damage can enable a prioritization of DRM interventions including protective structures and inform the BCA or CEA of the potential interventions.** For example, in the transport sector, the impact on disruption across the network can be measured by assessing the criticality of each segment (modeling when a road segment is damaged or blocked) and consequently to measure overall redundancy in the transport network. A case study from **Romania** demonstrates this approach (Box 8). Similarly, this approach was to assess roads in **Serbia** based on vulnerability and an economic analysis that examined the cost-effectiveness of interventions.[71] The methodology ranked roads in the country and helped inform the prioritization of proactive and resilient investments.[72] In **Albania**, a criticality analysis, combined with risk and cost-effectiveness assessments, was used to help stakeholders prioritize investments between different road sections and enhance resilience of road networks based on their risk levels and criticality.[73]

**BOX 8.** ROMANIA CASE STUDY: CRITICALITY ANALYSIS OF THE TRANSPORT SECTOR

The Romania case study presented in this report illustrates the use of sector-specific prioritization tools, focusing on transport as a critical sector. Using a multi-criteria and criticality analysis to evaluate Romania's transport networks, the case study shows that prioritization decisions can be informed through improved understanding about transport segments that are most vulnerable to specific hazards and most critical in terms of service delivery. The study identified those transport segments that are both critical and flood exposed, critical but not flood exposed, or not critical but highly flood exposed.

## PERFORMANCE-BASED APPROACH

**A performance-based approach evaluates DRM investments based on their effectiveness to reduce disaster risks or build resilience.** It focuses on evaluating actual performance of DRM measures rather than just assessing their inputs or outputs. The approach requires the definition of performance targets and indicators and prioritizes investments that enhance the performance of DRM measures. The advantage of the performance-based approach is that it is outcome oriented and provides a clear understanding of potential impacts. It may also help identify gaps that require additional investments. The effectiveness of this approach is however dependent on the ability to define meaningful and measurable indicators that accurately reflect the effectiveness of DRM measures.

70 For example, see Germany: Fekete, A. 2010. Criticality Analysis of Critical Infrastructures (CI)-Developing Generic Criteria for Identifying and Evaluating the Relevance of CI for Society. Link.
71 World Bank. 2018b. *Resilient Transport.* Link.
72 Vukanovic, S. 2018. *Climate and Disaster Resilient Transport Infrastructure*. Washington, DC: World Bank; Rozenberg et al. 2019. *From a Rocky Road to Smooth Sailing: Building Transport Resilience to Natural Hazards*. World Bank. Link.
73 Xiong, J., and X. Alegre. 2019. *Climate Resilient Road Assets in Albania*. Washington, DC: World Bank. Link.

**Specifically in view of critical sectors, decision-makers need to assess the effectiveness and potential impact of different DRM investments and prioritize those that offer the highest returns in terms of risk reduction and resilience building.** Targets and indicators with particular relevance for DRM would be given greater importance. By directing resources toward projects with higher performance scores, this approach aims to maximize the impact of DRM investments and enhance overall disaster resilience within a given context. In **Georgia**, for instance, a World Bank study collected exposure and seismic vulnerability information for 182 emergency response buildings across 150 sites to determine performance objectives and the recovery time under certain earthquake scenarios. To achieve the highest performance, the assessment identified the level of intervention required for all buildings in the portfolio and attested that eleven buildings are unlikely to achieve functional recovery standards and thus require replacement. The case study in **Bulgaria** showcases this approach by using key performance indicators (KPIs)—see Box 9 or Chapter 5 for details.

**BOX 9.** BULGARIA CASE STUDY: USE OF KPIS

The Bulgaria case study lays out practical steps and highlights applicable methodologies to facilitate prioritization of DRM investments in alignment with the EU's legislative frameworks, including the risk scenarios and DRGs, and EC initiatives and strategies on CCA adaptation. This case study also makes a link between DRM and CC agendas through the use of risk information and KPIs to help evaluate the effectiveness of considered DRM measures for extreme heat and wildfires.

## READY2RESPOND FRAMEWORK

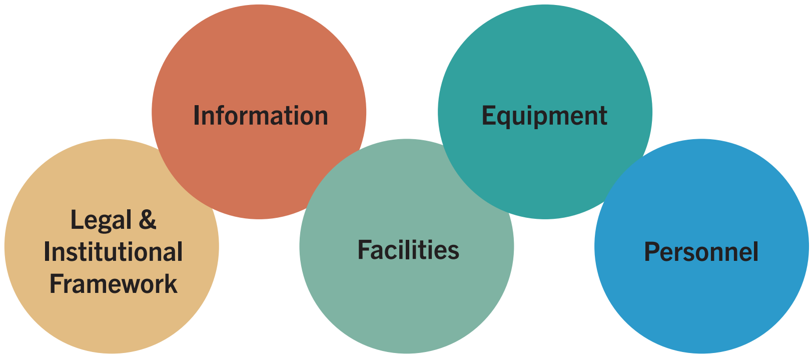
**The R2R framework was developed as a tool for DRM practitioners and decision-makers and to inform future policy actions and investments in disaster preparedness and response.** The approach can be applied at the national and subnational levels and is based on five functional components of traditional emergency preparedness and response capacities: (a) legal and institutional framework, (b) personnel, (c) facilities, (d) equipment, and (e) information. The framework ensures alignment with existing preparedness/response systems as well as international best-practice and provides considerations for system fault tolerance and business continuity. The five components together have 18 criteria, 72 indicators, and 360 attributes (Figure 18).[74] Examples of applications include **Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia** (Box 4), along with the **Croatia** case study (Chapter 5). Besides R2R, there are also other methodologies that assess capabilities related to DRM (for example, UCPM peer review assessment framework)[75] and/or for a phase of DRM or for a specific hazard (for example, EC wildfire peer review assessment).[76]

74 GFDRR. 2017. *Ready2Respond: Rapid Diagnostic Guide for Emergency Preparedness and Response.* Link.

75 Mysiak et al. 2021. *Union Civil Protection Mechanism - Peer Review Programme for Disaster Risk Management: Assessment Framework.* EC: Brussels, Belgium. Link.

76 Casartelli, V., and J. Mysiak. 2023. *Union Civil Protection Mechanism - Peer Review Programme for Disaster Risk Management: Wildfire Peer Review Assessment Framework (Wildfire PRAF).* EC: Brussels, Belgium. Link.

**Figure 18.** Components and indicative activities of the R2R approach




*Source:* Adapted from the GFDRR R2R report. Link.

**BOX 10.** APPLICATION OF THE R2R FRAMEWORK IN THE WESTERN BALKANS

**Context:** The Western Balkan region is vulnerable to a range of hazards, notably floods, droughts, earthquakes, landslides, and wildfires, some of which will become more intense and frequent as climate patterns evolve. Countries in the region face various challenges in advancing DRM, such as gaps in understanding and managing disaster risks, absence of risk management strategies, insufficient investment in human capacity and equipment, and lack of a systematic national analysis, among others.

**Approach:** To tackle some of these gaps, between 2021 and 2022, the World Bank, with financial support from the EU, completed six country-specific assessments of the current state of emergency preparedness and response and the associated investment needs for improvement of the overall system. The assessment was part of broader technical assistance focusing on different elements of key DRM, including strengthening national capacity for the prioritization and preparation of risk-informed investments. The R2R methodology was applied across six countries (Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia) to assess and provide an objective, data-driven foundation to engage country counterparts in emergency preparedness and response capacities.

**Results:** The assessment was conducted across relevant government institutions and focused on five components (legal and institutional accountability, information, facilities, equipment, and personnel) divided into 18 criteria, 72 indicators, and 360 attributes. Based on the findings, an investment report was prepared across these components, outlining possible investment scenarios in the short, medium, and long term and laying out the priorities for investments. Bosnia and Herzegovina and Albania used the results of the analytics as part of their application to UCPM.

*Sources:* Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia.

## CCA-RELATED APPROACHES THAT CLOSELY LINK WITH DRM

**There are also ways to prioritize investments in critical sectors and support disaster resilience as well as adaptation to climate change, which uses a mix risk-based and economic aspects.** In general, these criteria have been shaped because of the inherent uncertainty of the exact, localized disruptions that climate change will bring additionally to disaster risks determined mostly based on historical information of events. A broad matching of prioritization tools and decision criteria used in the DRM and CCA fields is presented in Table 3. Matching of CCA frameworks and DRM decision criteria and the individual approaches are outlined further throughout this section.

**Table 3.** Matching of DRM and CCA frameworks and decision criteria

| APPROACH | MATCHING CCA AND DRM DECISION CRITERIA |
|---|---|
| **TDR framework** | 'Win-win options' are adaptation actions that deliver the desired result in terms of minimizing the climate risks or exploiting potential opportunities and make a significant contribution to another social, environmental, or economic goal.<br>'Multiple-benefit options' provide synergies with other goals such as mitigation, DRR, environmental management, or sustainability (for example, ecosystem-based approaches usually provide such multiple benefits). |
| **Iterative risk management**<br>(BCA, CEA, RoR, sand so on) | 'Strategies that reduce decision-making time horizons' usually aim to respond to immediate and short-term needs by applying a stepwise investment starting with lower-cost options.<br>'Low-regret options' are adaptive actions for which the associated costs are relatively low and for which the benefits, although primarily realized under projected future climate change, may be relatively high. |
| **Decision-making under deep uncertainty/robust decision-making**<br>(MCA, AHP, criticality analysis, and so on) | 'No-regret adaptation options' are worthwhile whatever the extent of future climate change.<br>'Flexible or adaptive management options' are those options that can be adjusted easily (and with low cost), if circumstances change, compared to the projections made initially.<br>'Safety-margin strategies' aim to incorporate a margin of safety or redundancy into the design, operation, and management of an intervention, to increase the ability to cope with uncertainties and disruptions. |

*Source:* Adapted from World Bank. 2021. *Matching Approaches/Decision Criteria* adapted from EEA 2022. *Urban Adaptation Support Tool*. Link.
*Note:* AHP = Analytical Hierarchy Process.

## From Theory to Practice

**Prioritizing investments follows a structured approach with the aim of maximizing the impact of investments in resilience while adapting to evolving challenges.** The process involves goal setting and problem identification, baseline and sectoral analysis, development of prioritization frameworks, and implementation, with M&E playing a crucial role in ensuring effectiveness. Key elements of a prioritization framework comprise governance and strategic aspects, disaster and climate risk information, and socioeconomic factors which inform decision-making. A range of available analytical tools and approaches aid in prioritizing investment options, tailored to the specific context and objectives of a region or country.

**To foster a deeper understanding of the complex topics outlined above, this section translates the theory into practice by outlining a fictional use case with a visualized roadmap (see Figure 19).** Both serve as a versatile and effective tool for conveying complicated information and encourage the reader to think critically and apply the conveyed knowledge to solve resilience problems. By providing a practical example and a visual representation of the concepts discussed, readers can gain a clearer understanding of how theoretical principles can be applied in real-world scenarios. This aids in bridging the gap between theory and practice, with the next chapters providing real-life examples as well as new case studies to demonstrate the applicability of the presented process, framework, and analytical tools.

**In this fictional situation, a region faces severe wildfire risk, and its government identified the need for different risk reduction measures.** The story illustrates how different prioritization tools can be combined within a decision-making process and specifically within a prioritization framework to make better-informed decisions and select a portfolio of resilience investments. This example follows the **four key steps** of the decision-making process as outlined in Figure 14:

## I. PROBLEM IDENTIFICATION & GOAL SETTING:

➔ **STEP 1:** DEFINE PROBLEM, GOALS, AND TIMELINES

- The region of Salo Wald-Lesný is prone to frequent and severe wildfires due to its dry climate and dense forest cover. The local government has identified key challenges and recognized the need to invest in wildfire risk reduction measures and enhance the community's resilience. The overarching goals are reducing disaster risk, enhancing resilience and protecting critical sectors, and enhancing the resilience of a specific community. These objectives are aligned with broader national strategies related to DRM, CCA, and sustainable development, and will help establish a clear understanding of why DRM investments are being prioritized.

➔ **STEP 2:** CONDUCT STAKEHOLDER ENGAGEMENT

- The local government instructs its CP and emergency services agencies to investigate the issues, develop an action plan, and suggest several interventions to achieve the objectives. A steering committee is formed, and decision-makers start by engaging various stakeholders, including government agencies, community leaders, fire departments, environmental organizations, and residents to prepare the baseline analysis. They gather inputs and ensure that priorities are realistic and aligned with broader strategic and community needs and values. The stakeholder input helps in shaping the overarching goals and objectives and provides data and information that can be integrated into the framework.

## II. BASELINE AND SECTOR ANALYSIS

➔ **STEP 3:** IDENTIFY INITIAL OPTIONS/MEASURES

- Following a participatory approach, the steering committee conducts community consultations, workshops, and stakeholder meetings to gather inputs, insights, and local knowledge about the wildfire risks and the community's priorities. Initial consultations and review of DRM/sector-specific status (past/ongoing/planned measures and so on) helps pre-identify an initial set of potential measures or options which can guide the next steps.

➔ **STEP 4:** COLLECT INITIAL DATA

- In parallel with Step 3, a comprehensive risk assessment is commissioned to identify areas and assets most at risk from wildfires, which considers factors such as historical fire patterns, vegetation density, proximity to residential areas, evacuation routes, and vulnerable populations. As part of the initial data collection, teams also gather available climate risk projections and other key parameters to determine existing data gaps that help guide further data collection. This in turn will influence whether to pursue a more complex or a rapid/simplified approach.

***Note:***

- *In **data-rich contexts**, countries can employ advanced modeling techniques to simulate various scenarios and assess risks and prioritize investments based on the results of these models. Advanced data analytics tools furthermore allow the application of probabilistic assessments as well as the consideration of complex future climate scenarios.*
- *In **data-poor contexts**, the focus may be on filling key data gaps, through rapid surveys, consultations with local communities and experts, or use of global/other models or potentially other country analysis as proxy.*

Once the initial data are collected, decision-makers gather and evaluate results from the baseline analysis and identify a range of potential DRM investments including

- Community education and awareness program about wildfire risks, prevention measures, and evacuation procedures;
- Fuel management and vegetation control;
- Enhancement of firefighting capacities and purchase of new equipment;
- Installation of early warning systems, including sirens, text alerts, and a dedicated communication network to notify residents; and
- Investments in community resilience infrastructure such as shelters.

## III. PRIORITIZATION:

➔ **STEP 5:** DEVELOP A PRIORITIZATION FRAMEWORK

The steering committee considers the different elements of a prioritization framework and decides to apply a combination of different prioritization tools to evaluate the investment options including:

- Scenario-based approach,
- Cost-effectiveness analysis (CEA),
- Triple Dividend for Resilience (TDR) assessment, and
- Stakeholder consultation workshop.
- It also identifies and defines key prioritization criteria and data parameters including effectiveness in reducing risk, cost-effectiveness, feasibility, community acceptance, and potential long-term benefits, and assigns respective weights.

➔ **STEP 6:** CONDUCT DATA COLLECTION AND ANALYSIS IN LINE WITH THE FRAMEWORK

- The steering committee gathers the data necessary for the relevant planned steps in line with the decisions taken at the initial data collection step.

➔ **STEP 7:** CONDUCT DISASTER/CLIMATE ANALYSIS/ASSESSMENTS OR INTEGRATE EXISTING ANALYSIS

- The steering committee then analyzes the findings from the commissioned risk assessment from Step 4 which will serve as basis for the application of subsequent prioritization tools.

➔ **STEP 8:** APPLY SELECTED PRIORITIZATION TOOLS AND APPROACHES

- First, the development of several wildfire scenarios enables the steering committee to assess the effectiveness of the selected investments in reducing the impacts of bespoke scenarios. The scenarios include the high variability of impact scenarios that is brought about by climate change.

Depending on the approach chosen, this step and the next may include analysis of the costs and benefits of the chosen measures—it could be, for example, costs related to rehabilitation and reconstruction of infrastructure assets, upgrading/modernizing early warning stations, or costs related to nonstructural measures.

Through the subsequent TDR, the avoided losses and social, environmental, and economic co-benefits for each investment option are quantified and included in the overall analysis.

Lastly, in a stakeholder prioritization workshop, selected experts and DRM practitioners collectively evaluate the following criteria: effectiveness in reducing risk, cost-effectiveness, feasibility, community acceptance, and potential long-term benefits (determined under step 5).

➔ **STEP 9 AND 10:** ESTIMATE BENEFITS AND COSTS

Based on the outcomes of the prioritization workshop, decision-makers review the stakeholders' input, the CEA, and TDR.

They estimate the benefits of available options including potential risk reduction; resilience enhancement; and various social, economic, and environmental gains. These also include CCA/climate change mitigation (CCM) co-benefits, such as reduction of emissions in case of net-zero buildings. Other benefits such as broader societal benefits of having upgraded critical assets that cannot be easily quantified were still considered at the qualitative level.

In parallel, the steering committee also estimates the costs considering the design process, construction, maintenance and operation, staffing, training, and any other associated expenses.

➔ **STEP 11:** RANK INVESTMENT OPTIONS BASED ON CRITERIA

The steering committee reviews the investment options in light of overall priorities and available budget and ranks them based on the criteria and weights that were chosen previously. Decision-makers eventually decide to pre-select the community education and awareness program, the installation of early warning systems, and the purchase of a dozen new firefighting vehicles.

**STEP 12:** CONDUCT STAKEHOLDER ENGAGEMENT

To verify the analytical findings, the steering committee organizes another consultation with stakeholders and considers their feedback before making recommendations on the pre-selected measures/set of measures. This step ensures that the prioritization is inclusive, transparent, and accountable. It also provides another opportunity for stakeholders to contribute additional insights, knowledge, and concerns which might not have been fully captured in the initial stakeholder engagement.

**STEP 13:** REFINE ANALYSIS

- The latest stakeholder engagement determined that additional analysis to further refine the prioritization is not necessary and an additional layer of complexity could thus be avoided.

## IV. IMPLEMENTATION AND M&E:

**STEP 14:** DECISION AND IMPLEMENTATION

The prioritization process is successfully concluded, and the selected DRM investments are implemented according to the prioritization decision. The government establishes clear implementation plans, timelines, and responsibilities.

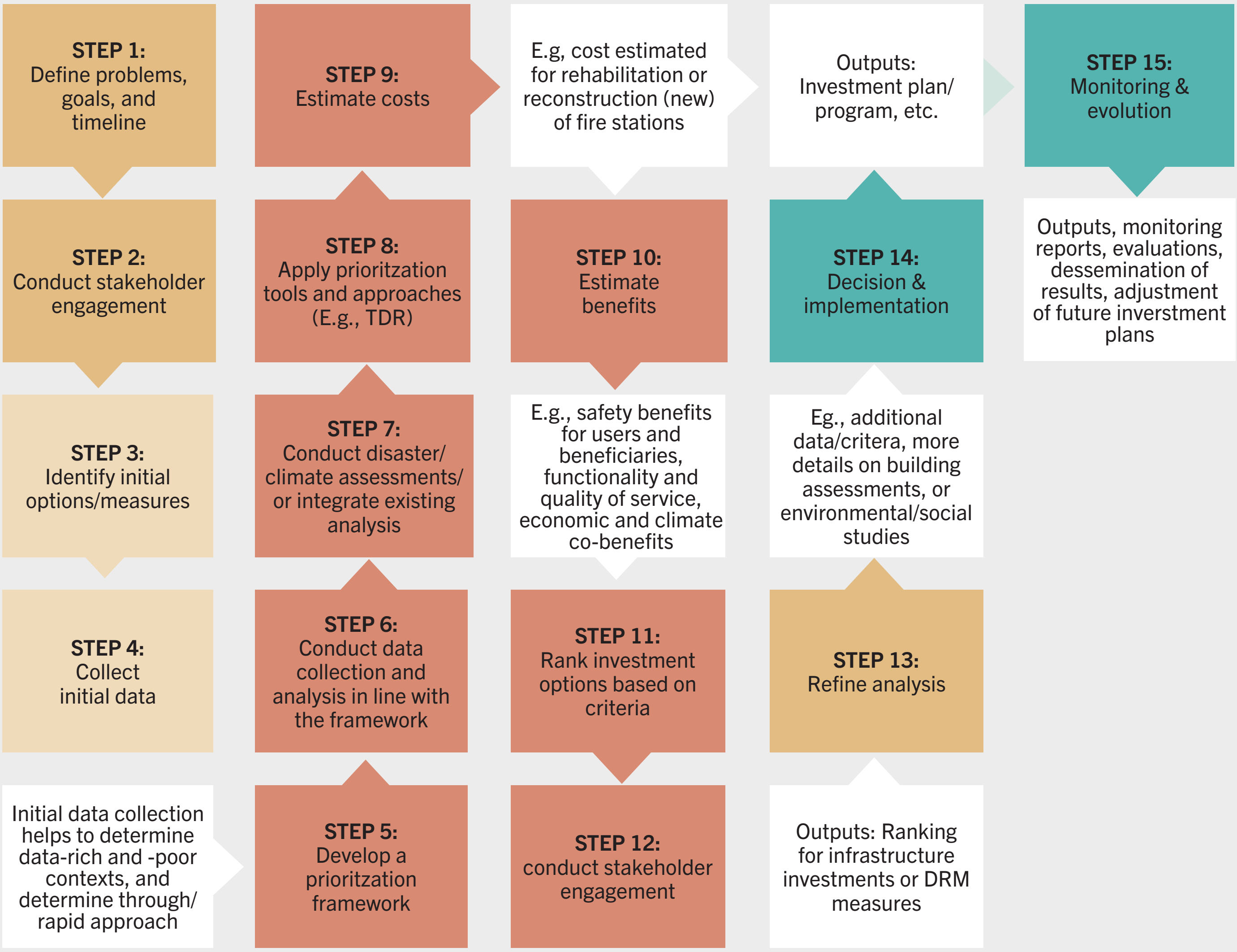
**STEP 15:** MONITORING AND EVALUATION

Regular M&E mechanisms are put in place to track the progress, effectiveness, and impact of the implemented investments. Feedback from stakeholders and local communities in Salo Wald-Lesný is actively sought and incorporated into the ongoing decision-making process.

An effective M&E framework helps identify any deviations from the planned activities or expected results, allowing for timely course corrections. It also offers opportunities to learn and improve current and future actions.

**The roadmap presented in Figure 19 visualizes the process for the above fictional use case.** The objective is to lay out the overall process and break down main decision points and expected outputs, which can inform better and effective choices. This general roadmap is aligned with the key stages presented above and can be broadly applied to different types of DRM investments, whether they focus on critical infrastructure or nonstructural measures or whether they are applied at different administrative levels.

**Figure 19.** Example roadmap for prioritizing DRM investments




*Source:* World Bank.

# 3. Existing Examples of Prioritization from Europe and beyond

**This chapter summarizes and draws out overarching lessons learned from existing examples of analytics and investments across Europe, and beyond, which used prioritization tools and can inform focused and smart investments in critical sectors.** The presented examples are organized by hazard, with emphasis on the most common analytical tools as described in the previous chapters, including MCA, BCA, TDR, criticality analysis, R2R, and portfolio- and performance-based approaches as well as the use of scenarios. The main lessons derived from these examples contribute to the overall recommendations of this report.

## KEY TAKEAWAYS

- **Smart actions require tailored solutions.** The review of existing examples confirms that a comprehensive and context-specific approach is crucial in DRM decision-making. Studies from Austria on extreme heat as well as the multi-hazard focus in Bulgaria and Greece emphasized the need for tailored prioritization frameworks that consider the unique geographic, climatic, economic, and social conditions of a country, region, or city. This approach recognizes that a one-size-fits-all strategy may not effectively address the diverse challenges posed by different disaster types and locations.
- **Smart actions require collaborative and balanced solutions.** Interdisciplinary collaboration stands out as a key factor in enhancing the effectiveness of prioritized investments in critical sectors. For example, when managing extreme heat and drought events, bringing together expertise from various sectors such as meteorology, engineering, environmental science, public health, and social sciences allows for a more holistic understanding of complex hazards and slow-onset risks. This collaborative approach in turn leads to a more balanced solution fit to address multifaceted challenges.
- **Smart actions require evidence and knowledge.** Reliable data and risk assessments serve as the bedrock of informed decision-making in DRM as shown, for example, by the examples on seismic risk in Italy or wildfires in Spain. Investing in robust data collection methods and improving data quality is imperative as robust quality data enable, for example, accurate predictions, comprehensive risk evaluations, and the development of effective early warning systems. This foundation of data-driven insights empowers decision-makers to make better-informed decisions and prioritize interventions

efficiently. However, as shown in the next chapter, even limited data can inform decision-making and lead to focused and smart decisions.

- **Smart actions require a vision and sustained efforts.** Long-term planning takes center stage in DRM, emphasizing the importance of sustained investments in resilience-building measures. This involves not only addressing immediate needs but also implementing infrastructure improvements and community capacity-building initiatives by adopting a forward-looking perspective. Romania, for instance, drew up its national seismic risk reduction strategy with a long-term vision to retrofit the built environment and assessed its nuclear power systems based on a long-term approach.
- **Smart actions require community focus.** Community engagement and effective risk communication emerge from this review as critical components in DRM. As shown by the example from Serbia, recognizing the significance of local knowledge and involving stakeholders in decision-making processes contribute to more resilient and sustainable solutions. Additionally, raising public awareness, especially regarding less visible threats like slow-onset disasters, is essential for garnering support and fostering a proactive approach to disaster preparedness at the community level.

## Examples of Prioritization by Hazard Type

### MULTI-HAZARD FOCUS

**Due to the complexity of different risk profiles, a flexible framework is needed to prioritize between different hazards and types of interventions.** As noted in Chapter 2, depending on the context, the MCA approach can be a useful tool to provide this kind of flexibility. For a multi-hazard assessment, the prioritization process demands a comprehensive risk assessment taking into account cascading risks and common risk drivers, coordinated and aligned efforts by different stakeholders across different sectors, capacity building and knowledge sharing, investments in structural and nonstructural infrastructure, community engagement, and adaptive management and course corrections when required.

**For example, both Bulgaria and Greece used MCA to inform the development of their NDRMPs.** The MCA approach allowed them to link their respective national-level risk assessments and climate considerations and prioritize among a range of measures proposed by different line ministries and other stakeholders related to various sectors and natural hazards. The prioritization framework used semi-quantitative MCA with six criteria: significance of risk, climate sensitivity, effectiveness, efficiency, sustainability, capacity, and urgency. In Bulgaria, the prioritization was grouped by short-, medium-, and long-term DRM investment goals at the national level, considering the input from a multitude of stakeholders. In Greece, the prioritization was structured by prevention, preparedness, and response measures and comprised a consolidation of planned and proposed measures as well as financing opportunities to manage the multi-hazard risks.

**For both Greece and Bulgaria, the respective NDRMPs allowed both countries to access EU funds for DRM.** The development of the NDRMPs is an enabling condition[77] to access funds available to EU MSs, particularly under Policy Objective 2 (PO2) of the Cohesion Policy on “greener, low carbon transitioning towards a net zero carbon economy.”[78]

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77 Effective DRM framework: A national/subnational DRM plan based on risk assessments, considering impacts of climate change/CCA strategies, including a description of key risks (Art. 6(1) Decision No 1313/13 indicative 25–35 years; description/prioritization of DRM; and available financing resources/mechanisms for operation and maintenance costs on DRM. (EU. 2021. *Regulation 2021/1060*. Link.).

78 Intervention areas under this policy area include CCA measures; prevention and management of climate-related risks such as fires, storms, drought, floods, and landslides (including awareness raising, CP and DRM systems, infrastructure and ecosystem-based approaches); prevention and management of non-climate-related natural risks (for example, earthquakes); and risks to human activities (for example, technological accidents). As of October 2023, the total budget under PO2 was €133.5 billion (€96.8 billion in EU contribution). The CF consists of 19.1 percent, while the ERDF consists of 80.9 percent. (EC. 2023b. *Policy Objective: Greener Europe.* Cohesion Open Data Platform. Link.).

Under this PO2, countries can access funds from the ERDF, and CF, and related subprograms. Countries use these available funds for DRM through their regional/operational programs (OPs), often focusing on environment (for example, flood production) or sustainable development.

**The process of prioritization itself also had broader benefits**. The MCA approach within Greece's DRM plan also informed the decision to develop a dedicated OP for CP, AEGIS (more information in Box 9). In Bulgaria, DRM is considered under the OP dedicated to environment, which prioritizes circular and blue economy, energy efficiency, water supply and sanitation, clean air, disaster risk prevention, and biodiversity. Based on the NDRMP, this OP aims to improve the prevention of the risk of extreme events through early forecasting, modeling, and warning; improve DRM (floods, droughts, forest fires); promote the implementation of green measures and ecosystem-based solutions aimed at flood prevention and protection (an identified priority); and introduce modern methods and technology to support DRM.[79]

**BOX 11.** PRIORITIZING INVESTMENTS AS PART OF NATIONAL POLICY FRAMEWORKS FOR DRM IN GREECE

In Greece, a simplified MCA was used to prioritize the NDRMP measures (see the example in Table 4). The MCA was carried out independently for the measures for each hazard; a standardized score on a three-point scale (range of 1 to 3) was applied for each of the evaluation criteria and the relative weight of criteria: significance of risk (20 percent), climate sensitivity (10 percent), effectiveness (20 percent), efficiency (20 percent), sustainability (10 percent), capacity (10 percent), and urgency (10 percent). The weights of individual criteria affect the ranking and selection of investment priorities in the NDRMP, and the final ranking of NDRMP measures is based on a weighted total.

**Table 4.** Example MCA for the NDRMP for Greece

| EVALUATION CRITERIA | SIGNIFICANCE OF RISK | CLIMATE SENSITVITY | EFFECTIVE-NESS | EFFICIENCY | SUSTAINA-BILITY | CAPACITY | URGENCY | FINAL SCORE |
|---|---|---|---|---|---|---|---|---|
| **Weight** | 20% | 10% | 20% | 20% | 10% | 10% | 10% | 100 |
| **Proposed interventions** | | | | | | | | |
| **Measure 1** | 2 | 1 | 2 | 3 | 3 | 1 | 2 | **1.9** |
| **Measure 2** | 3 | 2 | 1 | 3 | 3 | 3 | 3 | **2.2** |
| **Measure 3** | 1 | 3 | 3 | 1 | 1 | 2 | 1 | **1.6** |
| **Measure 4** | 2 | 2 | 2 | 2 | 2 | 1 | 3 | **1.7** |

*Source: Ministry for Climate Crisis and Civil Protection. 2021. Inputs and Recommendations for the Development of a Draft NDRM Plan for Greece. World Bank.* Link.

In Greece, the sectoral OPs finance actions of national or strategic importance, including risk management, biodiversity and NATURA sites, solid waste management infrastructure projects, energy saving projects in residential buildings, supply of CP equipment, targeted strategic flood protection projects, awareness-raising and human resources training actions, and horizontal projects. To implement priority DRM measures, Greece's National Program for Civil Protection, AEGIS,[80] aims to upgrade CP infrastructure and equipment. About €1.97 billion is allocated, drawing on (a) a new OP within the ESIF 2021–2027 focusing exclusively on CP (€714 million),[81]

79 EC. 2022. Partnership Agreement with Bulgaria - 2021–2027. Link.

80 Transport Infrastructure, Environment, and Sustainable Development (Ymperaa). 2021. Civil Protection Program. Link.; Government of Greece. 2020. Law 4662/2020.

81 The main aim is to finance the creation of a modern and effective CP mechanism that focuses on prevention, preparedness, response, and intervention to protect the life, health, and property of citizens—as well as cultural heritage, infrastructure, the natural environment, resources, vital services, and tangible and intangible assets—from natural and technological disasters and other related threats that could cause emergencies. This co-funded total is listed in the Partnership Agreement that was approved in July 2021. (Government of Greece. 2021. *Partnership Agreement*. Link.). This OP was approved on June 16, 2022.

(b) the NRRP for infrastructure upgrading and prevention projects (€408 million), (c) a European Investment Bank loan (€595 million), and (d) a proposed special development program for CP within the National Development Program 2021–2025 which focuses on the management prevention of impacts of natural hazards on infrastructure.

Greece has devoted 37.5 percent of the NRRP to climate objectives, including measures to enhance the operational capabilities of Greece's CP and disaster management systems to address climate-related risks, such as floods and forest fires.[82] For example, the NRRP includes several investments in DRM/CP under Axis 1.4 Green Transition Pillar**,** such as development of aerial means for crisis management, development of an innovative monitoring and management system, establishment of a strategic NDRMP,[83] forest firefighting, risk prevention, reforestation, response equipment, and implementation of Regional Civil Protection Centers (PEKEPP) through public-private partnership (PPP) schemes.[84]

**In Albania, a multi-hazard (floods, earthquakes, landslides) prioritization assessment was conducted to inform resilience-building initiatives of the national road transport networks based on vulnerability and economic criteria.** It comprised hazard-specific risk analysis, identification of mitigation measures, and a classic BCA. The EURO-CORDEX data set and Emergency Events Database (EM-DAT) were used to gather data on past hazard events and from existing rehabilitation projects, and cost-effectiveness and vulnerability criteria informed the framework of interventions. The prioritization of mitigation measures into the Road Asset Management Systems (RAMS) was then based on the risk and vulnerability assessments (see Box 7).

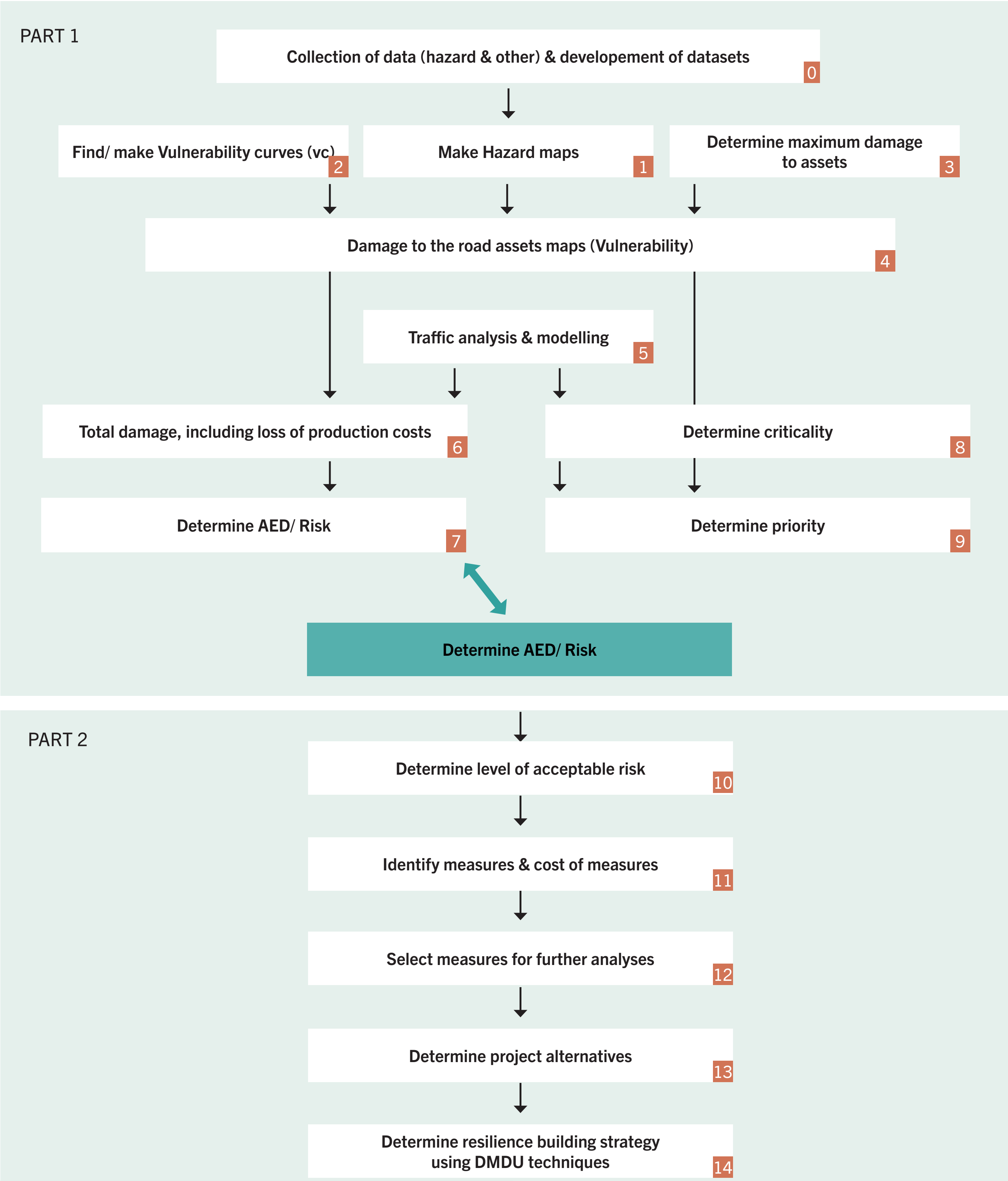
**BOX 12.** APPLICATION OF CRITICALITY ANALYSIS FOR THE ALBANIA ROAD NETWORK

**Context:** To help Albanian stakeholders with the prioritization of current and future climate and seismic investments in road assets, a World Bank assessment[85] on the cost-effectiveness of the implementation of disaster risk mitigation measures on an Albanian road network was undertaken in 2019. In the case study, a 1,494 km national road network was examined, with 1,370 km as primary roads and the remaining as secondary roads on request of the Albanian Road Authority (ARA). In the assessment, the values of roads, bridges, culverts, and tunnels within the network were measured, and the potential impacts of floods, earthquakes, and precipitation- and seismic-induced landslides on the primary road network were examined.

**Approach:** The case study used criticality analysis to assist the prioritization of interventions. The assessment was conducted for different road corridors and included two parts: (a) a risk analysis and (b) mitigation measures and BCA. The objectives of the two parts were achieved through a combination of 13 actions (Figure 20). During the risk analysis process, vulnerability maps that show the expected damage to the roads per hazard, as well as risks maps based on Annual Expected Damage (AED), were developed to help identify the road sections that require a higher prioritization for investments. Then, in Step 9, a priority map was developed to assist the Road Authority to find locations where the investments in building resilience should be made first, based on the total economic damage and criticality analyses.

82 EC. Greece's NRRP. Link. *See also* Government of Greece. Greece 2.0. Link.
83 The Renovation of Buildings Initiative aims to promote comprehensive building renovation focusing on ensuring healthy indoor climate conditions, fire protection, and addressing risks associated with seismic activity.
84 EC. 2021b. *Commission SWD (2021) 155 COM (2021) 328.* Link.
85 Xiong and Alegre 2019.

**Figure 20.** Criticality analysis and risk and vulnerability assessment for the Albanian Road Network




**Results:** The framework suggested that the corridors at highest risk and highest criticality should be prioritized for risk reduction interventions. Meanwhile, prioritization should also be given to measures that were economically feasible and could yield the most benefit according to the sensitivity analysis and BCA. The case study demonstrated that criticality analysis, combined with risk and cost-effectiveness assessments, could be used as an adequate tool that helps stakeholders prioritize investments between different road sections and enhance resilience of road networks based on their risk levels and criticality.

## FLOODS

**Flood risk management investments often require complex processes and a combination of multiple approaches.** Flood risk analysis is a multidisciplinary approach requiring input from hydrological, geological, and engineering perspectives as well as a deep understanding of socioeconomic factors. Alongside risk-specific analysis, decisions in flood risk management investments require the consideration of various additional aspects including effects on ecosystems and biodiversity, social acceptability, technical feasibility, cascading risks, and so on.[86] The classic BCA is not always well suited to address this, and a mix of different approaches has proven more useful to better evaluate flood risk-related interventions. An example from the United States shows the limitations when decision-makers rely solely on a single prioritization tool for interventions in flood risk management (see Box 11).

### BOX 13. EXAMPLE OF OVERRELIANCE ON A SINGLE PRIORITIZATION TOOL

Richwood, West Virginia in the United States, is a small community and highly exposed to flood risk. In 2010, the town counted about 2,100 people and more than 30 percent of its residents lived below the poverty line. According to data from First Street Foundation, 43 percent of the city's properties were exposed to severe flood risk. The city council had tried to fund mitigation projects for decades through the Army Corps of Engineers, the US Department of Agriculture, and Federal Emergency Management Agency (FEMA) programs. However, the BCR was not high enough to secure funding in any of these applications because of the community's low property values. With no solution in place, the community experienced devastating flooding in 2016 when nine inches of rain fell within 24 hours. Eighty homes were damaged, 100 homes were destroyed, and broader economic losses rippled through the community—including the closure of a nursing home and the local grocery store. The BCA's overemphasis on property values created a barrier for Richwood to access critical federal funding for mitigation, putting its most vulnerable residents at risk.

**Alternative approaches such as MCA, criticality modeling, TDR, or participatory approach tend to produce more meaningful and reliable results in this case than the classic BCA.** In Serbia, for example, where 70 percent of damage during 2014 floods happened at the local level, a mix of criticality modeling, MCA, and a participatory approach was used to prioritize flood risk reduction measures (Figure 21).[87] The criticality was assessed based on vulnerability (therefore priority for intervention) and the cost-effectiveness of interventions was based on the impact costs avoided and implementation costs. Though based on limited information, the model undertook an economic analysis that examined the cost-effectiveness of roads, which helped inform more proactive and resilient investments in the country. The advantage of the MCA was that it supported the engagement of local stakeholders in the decision of what was critical to meet prioritized development goals and increased awareness of local decision-makers about the importance of increasing resilience to ensure transport connectivity. Stakeholder inputs were used to assign values to essential services that generate welfare for a community (for example, schools, hospitals, and economic output). In doing this, the MCA closed a gap particularly prevalent in implementing climate adaptation measures, which has multifaceted impacts that are not easily quantifiable.

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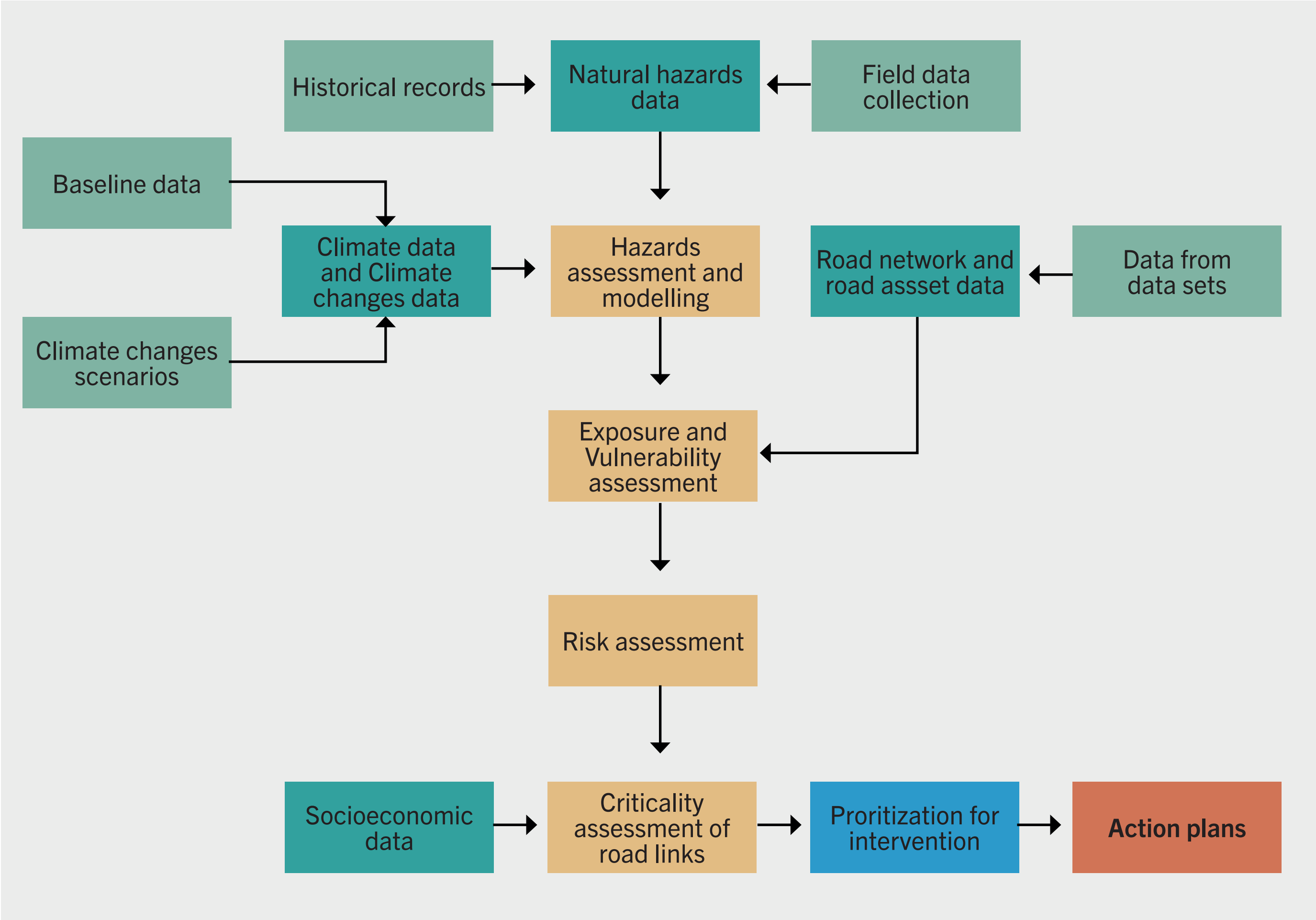
86 Jha, A., R. Bloch, and J. Lamond. 2012. *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*. Washington, DC: World Bank. Link.; van der Pol, T. D., E. C. van Ierland, and S. Gabbert. 2017. "Economic Analysis of Adaptive Strategies for Flood Risk Management under Climate Change." *Mitigation and Adaptation Strategies for Global Change* 22. Link.

87 World Bank 2018b.

**Figure 21.** Methodology for road network criticality assessment in Serbia




*Source:* World Bank 2018. Adapted from Biljana Abolmasov's presentation.

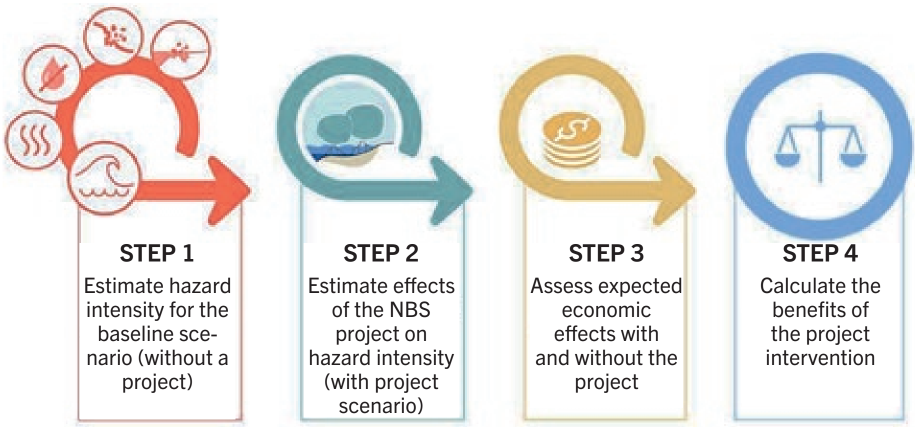
**The Delta Program in the Netherlands is a relevant example of a multistage risk-based, participatory, and BCA approach incorporating, whenever possible, NBSs for flood-related investments.** Introduced following devastating floods in 1953, the Dutch government implements different DRM measures along the coastline to protect its population from future flooding, heat, and drought and secure a sufficient supply of freshwater for farming, industry, and nature itself.[88] Investment decisions are made following a multistage process including the analysis of current and future risks, consultations with stakeholders, application of a classic BCA approach, and considering other factors such as technical feasibility, social acceptability, and political support to complement the BCA. On this basis, the program selects every year dozens of measures that have the highest net societal benefit and prioritizes their implementation accordingly. See Box 12 for more information about valuing NBSs for resilience.

88 Government of the Netherlands. 2021. *National Delta Programme 2021.* Link

## BOX 14. VALUING NBSS FOR RESILIENCE

Besides risk reduction benefits, NBSs provide several other co-benefits which should be valued and added in a decision framework when valuing the strengths and challenges of individual NBSs. Per the below-referenced report, decision-makers can draw on a diverse set of economic and noneconomic indicators for estimating the co-benefits of the NBS for climate resilience, including market price, replacement costs, avoided damage, social costs, production functions, and contingent valuation. Figure 22 outlines the four-step process of valuing risk reduction benefits using the avoided damage method. The report also includes a practical guide on how to decide on the right valuation approach and comprises eight case studies from around the world which illustrate different valuation approaches and help better understand, prepare, and implement similar projects.

**Figure 22.** Estimating NBS benefits and costs




*Source:* World Bank/GFDRR 2023.

**In Ireland, a mix of risk-based and participatory approach has successfully been applied for actions under the Catchment Flood Risk Assessment and Management (CFRAM) Programme[89] and across a broad range of multisectoral objectives.** The prioritization of interventions was based on simple, participatory approaches and considering nonmonetary, broader benefit of flood risk reduction measures.[90] The assessment was multisectoral, covering transport, utilities, health, and agriculture, and implemented at the national level. A qualitative MCA framework was used to prioritize potential risk reduction measures. The prioritization framework was based on the cost-effectiveness of the measures and considered three pillars: people (social), economy, and environment. To assess present and potential future flood risks across Ireland, flood maps were created based on extensive and detailed hydraulic models. One present-day and two future scenarios (one 'mid-range' and one 'high-end' scenario, which represent the mid-range and high-end outcomes of all Intergovernmental Panel on Climate Change [IPCC] scenarios) were modeled and mapped. This scenario-based approach identified flood zones in Ireland, which help authorities with spatial planning and prioritize protective measures to reduce flood risks and impacts. As a result, the program has identified measures to provide protection for approximately 80 percent of properties in the country from flood risks from rivers and the sea.[91]

89 For more details, *see* Government of Ireland. 2021. *CFRAM Programme*. Link.
90 EC 2021f.
91 EC 2021f.

**A relevant example of the risk- and scenario-based prioritization tools comes from Romania where a large-scale, national-level quantitative assessment of nuclear power system based on long-term, real-world data was carried out to inform decision-making.**[92] The assessment included flood risk analytics and impact scenarios and produced an overview of effects on the national electricity system and nuclear power infrastructures. Through an integrated geo-referential approach, the analysis modeled the interdependencies of critical infrastructures in power systems at the national and EU levels and enhanced awareness and prioritization of vulnerabilities, with different return periods and probability of occurrence taken into account. The study suggested the integration of Romania in the Critical Infrastructure Warning Information Network (CIWIN) which would allow informing/warning operators of critical infrastructure about the probability of being affected and contain or eliminate potential danger.

**A method used to prioritize the protection of Croatian transport infrastructure was a scenario-based criticality analysis combined with Analytical Hierarchy Process (AHP).** As part of the EC-funded INFRARISK project, a mix of qualitative and quantitative methods has been performed to stress-test the national railway network in Croatia.[93] A two-stage risk impact assessment identified and prioritized the most vulnerable components of the network by first calculating the direct costs of physical repairs to the network as a result of flooding and then establishing the indirect consequences of travel delays for passengers and freight transport. Infrastructure vulnerability was then prioritized according to the direct losses (repair costs) and indirect losses (transport disruption) under extreme flood event scenarios. According to the authors of the study, the applied stress test framework can be adapted for other infrastructure types, such as power, telecommunication, and water distribution networks, to evaluate potential losses associated with extreme natural hazard events.

## WILDFIRES AND ASSOCIATED AIR POLLUTION

**Prioritizing investments in wildfire risk reduction and prevention can be complex, however, there are many examples of robust analytics and prioritization efforts.** In Europe, the prioritization framework for wildfire prevention and preparedness interventions can take various forms, with different social, economic, environmental, and governance aspects considered. Such frameworks can be used by policy makers to prioritize wildfire prevention strategies between national and subnational levels and make crucial decisions in prioritization between and within different types of interventions in wildfire prevention and preparedness. Policy makers need to make choices on how to prioritize measures and plans implemented at the national and subnational levels, which usually requires collaborations between different authorities and stakeholders. Furthermore, decision-making for wildfire risk management requires expertise in many areas, including fire management, ecology, forestry, agricultural systems, and GISs and should consider several factors such as the weather, vegetation, fuel management, land use patterns, and human behavior.

**Various criteria have been used in prioritization decisions for wildfire prevention and preparedness**. In general, based on assessments of potential wildfire risks and impacts and evaluations, measures and resources for wildfire prevention and management are usually prioritized in areas with high fire risks within a country. Nevertheless, other aspects, such as social vulnerability, ecological values of forestry, and the effect of climate change on the future trends of wildfires, are also often being considered in the prioritization strategies. With social and environmental aspects taken into account, priority in post-fire response is given to life safety and evacuation. Recovery often prioritizes and recovery lands with high economic or ecological value, while climate change and projection on future fire trends often lead to prioritization choices between strategies designed for different time spans. Governance is another crucial element in making prioritization decisions,

92 Marinescu et al. 2017. *Critical Infrastructure Risk Assessment of Romanian Power Systems*. Link.
93 Clarke, Corbally, and Obrien 2016.

especially noteworthy in countries with comprehensive, well-established legislative frameworks and regulations on forest and wildfire management. Climate change is furthermore a source of extreme uncertainty and amplification of risk. Wildfires, in turn, are a major driver of carbon emissions, poor air quality, and business/industry downtime. Consequently, the most common approaches to prioritize wildfire investments include risk- and scenario-based approaches combined with either a BCA or MCA.

**Portugal is a country that has significantly increased its efforts in the prevention and preparedness for wildfires, by focused and smart prioritization of these investments in their strategies and budgets** (in alignment with global/EU-level efforts). Table 5 shows how prioritization can take place across different levels, as well as *between* as well as *within* different intervention types of investments. This comprehensive yet prioritized approach allows Portugal to address specific gaps and challenges in an effective manner. Below are two examples showing efforts using risk information and analytical approaches. More information about Portugal's national prevention and preparedness program "Safe Village, Safe People" (SVSP) is discussed in Chapter 4.

**Table 5.** Prioritization levels for wildfire prevention and preparedness investments (example Portugal)

| | | | | | | |
|---|---|---|---|---|---|---|
| **PRIORITIZATION LEVEL 1:**<br>**Harmonizing various global and EU level strategic goals and standards** | | | | | | |
| **Disaster Risk Reduction and Prevention**<br>e.g. Sendai Framework for Disaster Risk Reduction 2015–2030 | | | | | | |
| **Adaptation under European Frameworks**<br>e.g. EU Forest Strategy, CCA Strategy, Green Deal, DG EU DRGs / scenarios, building codes... | | | | | | |
| **Response and Capacity Building**<br>e.g. UCPM activation and Civil Protection Mechanism, Greening the CP Sector... | | | | | | |
| **PRIORITIZATION LEVEL 2:**<br>**Between national / regional / local strategic frameworks and plans** | | | | | | |
| **Portugal: well-developed strategies for wildfire prevention and response**<br>• 2020 – 2030 national plan for integrated wildland fire management<br>• 2020 – 2030 Fuel Management Plan<br>• 2021 Integrated Rural Fire Management System (SGIFR)<br>• National Strategy for Preventive Civil Protection<br>• Regional/local strategies and plans | | | | | | |
| **PRIORITIZATION LEVEL 3:**<br>**Between interventions types** | | | | | | |
| Capacity Building and CP Resources | WUIs management | Forest Management | Fuel Management | Post-fire restoration | Coordination & collaboration mechanisms | Early Warning & Knowledge |
| **PRIORITIZATION LEVEL 4:**<br>**Within intervention types** | | | | | | |
| Firefighting and rescue services, CP infrastructure | WUI raster maps and building codes | Forest management in different areas and for different agents | Fuel break for rural housing, civil protection resource prioritization in cross-border areas | Reforestation for silvi-culture, biodiversity and ecosystem services | Mutual assistance across countries, firefighting collaboration between authorities and private companies | Fire alarm and forecasting, information campaign |

*Source:* World Bank.

**A risk- and scenario-based approach was used to inform targeted investments in fuel management.** A wildfire risk assessment simulated 10,000 fire seasons to determine exposure to buildings, communities, and the natural areas and their capacity to adapt to changing circumstances.[94] The analysis was used to update the national fuel management plan and highlighted vital priorities to safeguard the most vulnerable communities and promote landscape management programs at the national level. The wildfire simulation modeling approach presented in this study is extensible to other fire-prone Mediterranean regions where predicting catastrophic fires can help anticipate future disasters.

**A recent study by Nunes et al.[95] on wildfire risk in Central Portugal looked at the spatial variations in wildfire hazard at WUIs to inform focused strategies in management, preparedness, and mitigation plans.** The use of WUI as a spatial risk analysis unit is an innovative approach and enables the assessment of a location's susceptibility to wildfires when overlaid with wildfire risk models. By applying this method, locations with higher levels of hazard can be identified which enables guiding the design of spatially targeted strategies in management, preparedness, and mitigation plans. The study results showed that more than half of Central Portugal is susceptible to high and very high wildfire risk, and the municipalities with the highest risk are located inland and in mountainous areas. Locations where urban zones and wildlands meet or intermingle are shown to have a positive relationship with the risk of wildfires igniting. The method presents a practical approach to identify risk areas and prioritize investments, although this research did not include socioeconomic factors, type of construction, coping capacity, and other variables in its analysis.

**In South of France, a risk-based approach and network criticality analysis led to improved understanding of gaps within specific critical sectors among various stakeholders.** An impact assessment with tabletop input from stakeholders was carried out to better understand the effects of forest fires on interconnected critical infrastructures (electricity, roads) considering different climate scenarios and produced a relevant methodological framework.[96] The focus was placed on network vulnerability and interdependencies. The prioritization framework was co-created with local stakeholders including academia, emergency responders, and infrastructure operators who helped validate disaster scenarios and identified cascading effects on critical infrastructure. The assessment led to an increased awareness of climate change impacts and vulnerabilities and inter-dependencies between networks from different types of critical infrastructure operators, first responders, and subnational emergency management authorities. The lack of considering extreme scenarios in operational plans furthermore demonstrated the need to start thinking more holistically about investments which in turn will inform future infrastructure design and emergency response.

**A risk- and scenario-based MCA approach was applied in Greece to determine priorities on forest management for wildfire risk mitigation and community protection.** The scenario planning model explored different strategic approaches to allocate fuel treatment projects and evaluate efficiency and trade-offs.[97] The analysis focused on risk data in the field of forest management and developed an optimization framework to evaluate five priorities: protection of developed areas, optimized commercial timber harvests, protection of ecosystem services, fire resilience, and reducing suppression difficulty. A multi-criteria spatial method was then used to determine trade-offs between the priorities. The project is a good example of how to incorporate economic modeling in scenario planning with the ultimate purpose of calculating harvest costs and commercial value of different timber types.

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94 Alcasena et al. 2021.

95 Nunes et al. 2023. "Assessing Wildfire Hazard in the Wildland–Urban Interfaces (WUIs) of Central Portugal." *Forests* 14: 1106. MDPI: Basel, Switzerland. Link.

96 Sfetsos et al. 2021. "Assessing the Effects of Forest Fires on Interconnected Critical Infrastructures under Climate Change. Evidence from South France." *Infrastructures* 6 (2): 16. Link.

97 Palaiologou et al. 2021. Spatial Optimization and Tradeoffs of Alternative Forest Management Scenarios in Macedonia, Greece. Link.

**Following a risk-based fire simulation modeling approach, a subnational study assessed exposure metrics and completed a spatial prioritization for Catalonia, Spain.**[98] Adopting a holistic and long-term approach, the study looked at a set of management options aimed at creating fire-resilient landscapes, restoring cultural fire regimes, facilitating safe and efficient fire response, and creating fire-adapted communities. The exposure metrics were combined with land use maps and historical fire occurrence data to prioritize different fuel and fire management options at the municipality level. The study ultimately contributed to understanding human ignition prevention, limiting structural damage to buildings, and identifying opportunities for response. The results also invigorated thinking about localized programs to build defensible space and improve self-protection of communities which is replicable in other fire-prone Mediterranean areas. The study may also prove useful for potential future policy adjustments at the local level including temporary bans on recreational uses in protected areas and public forests to avoid human ignitions and others.

**In Italy, for ex post wildfire recovery and forest restoration, funds of the Rural Development Program were allocated toward priority areas according to multiple prioritization criteria.**[99] Cultural heritages and ecological services are often prioritized in such recovery and restoration programs. For instance, after nine large fires in 2017, the 'Piano Straordinario Incendi Boschivi' program was established in the Piemonte Region. The program prioritized areas for prevention and restoration activities based on factors such as the value of forest ecosystem services, fire severity, and a participatory program that involves local populations in areas affected by the major wildfire events.

## EARTHQUAKES

**Seismic strengthening programs at scale require large capital investments, risk assessment, and planning.** Such programs are typically designed to prioritize vulnerable buildings and infrastructure that are at high risk, are critical, or are of strategic importance. Therefore, the risk assessment, BCA/MCA, and TDR approach—to be able to quantify broader socioeconomic and environmental (such as CCA) benefits—are common tools in helping prioritize and plan for seismic risk reduction investments. As with other hazards, there is a need for careful consultations with the communities.

**The benefits of seismic strengthening are commonly determined by considering the difference in social and economic losses caused by earthquake damage with and without the intervention.** Probabilistic or scenario-based earthquake risk analysis is used typically to quantify the reduction in post-earthquake repair costs—the main considered benefits. A reduction in repair cost as the sole benefit in a probabilistic risk analysis does not typically result in a positive return rate on a retrofit investment (even though in a single earthquake the returns could be large). This results from the fact that the annual probability of a large earthquake is usually low (that is, infrequent high-severity event). To reflect a more representative benefit of a seismic investment, reduction in fatalities, injuries, and business interruption losses should be considered as benefits or a scenario-based approach (that is, what-if analysis) employed.

**The risk-based scenario approach was used to perform a seismic risk assessment of emergency response facilities and inform focused investments in several countries.** A combination of risk-based and governance/strategy-related approaches was applied in Romania. Using such a hybrid prioritization framework, specific investments were selected based on portfolio-wide assessment of seismic risk in the country combined with the criticality of each building.

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98 Alcasena et al. 2019. T*owards a Comprehensive Wildfire Management Strategy for Mediterranean Areas: Framework Development and Implementation in Catalonia, Spain.* Link.

99 Regione Piemonte. 2019. *Piano straordinario di interventi di ripristino del territorio percorso dagli incendi boschivi dell'autunno 2017.* Link.

The framework also considered benefits and costs, including of integrating energy efficiency measures as part of a 'smart' package of investments. Based on this analysis, a prioritized list of more than 67 critical emergency response facilities under the ownership of the Ministry of Internal Affairs will be retrofitted/reconstructed with modernize emergency infrastructure to provide 3,000 first responders with disaster-resilient, energy-efficient, gender, and disability-friendly facilities that meet modern response requirements. [100] Millions of citizens are expected to benefit from improved emergency services. The investments or resilience of emergency response buildings are expected to yield benefits up to two times higher than the costs.

**In Georgia, a risk-based scenario approach was used to perform a seismic risk assessment of emergency response facilities.** Based on different earthquake scenarios, loss of functionality was estimated for 182 buildings across the country. The recovery time was estimated for cases with enhanced preparedness and without and impacts on workforce and facilities as well as on access of the population to emergency services were also estimated. The post-earthquake functionality was then considered in the prioritization of retrofitting and reconstruction investments for different facilities.

**Related to public building strengthening, examples from Italy and more recently from Romania show how multiple scenarios and approaches can inform for the allocation of funding.** A scenario-based BCA approach was used to evaluate the 2010–2016 National Plan for Seismic Risk Prevention implemented by the Government of Italy, which aims at strengthening private residential and mixed-use buildings and retrofitting of public buildings.[101] By modeling the consequences of multiple earthquake scenarios with and without earthquake strengthening interventions, the assessment quantifies the benefits of the interventions as a decrease in losses and damage and evaluates the benefits based on two analyses: a decrease in average annual loss (AAL) and a decrease in losses in a probable maximum loss (PML) analysis (475-year return period, rare event). The results of the analysis show BCR more than 1 for local strengthening interventions and BCRs less than 1 for other intervention types for AAL and positive BCRs for all intervention types for public buildings in the PML analysis. Furthermore, a recent publication on the seismic upgrading of critical buildings demonstrated that so far interventions on more than a thousand of buildings have been financed through the National Plan for Seismic Risk Prevention.[102] Seismic retrofit intervention types include local strengthening, seismic upgrading, and demolition and reconstruction in compliance with the Italian National Technical Standards for Construction (NTSC) issued in 2008 and updated in 2018. Regarding financial measures in support of the building renovation of private buildings, there have been a number of incentives for private owners such as Sisma-bonus incentive which offers a tax deduction equal to the expenses incurred for strengthening interventions on buildings in seismic zones 1–3.

**In 2022, Romania adopted a National Seismic Risk Reduction Strategy, the first document to provide a long-term vision on retrofitting Romania's built environment.** The strategy presents a three-layer approach to assessing vulnerability, including (a) national-level probabilistic assessments, (b) a citywide rapid visual screening, and (c) technical surveys and expertise. According to this multilevel prioritization, funds are to be allocated based on the risk level and directed toward the priority areas and buildings where the largest number of people can be moved to safety in the shortest time. In addition, Romania started implementing its National Program for the Consolidation of High Seismic Risk Buildings (that is, buildings classified in seismic risk class I or II). The program finances the design and execution of intervention works for two types of high-seismic risk buildings: (a) multistorey buildings having primarily a residential purpose and (b) buildings of public

100 World Bank. 2019a. *Improving Resilience and Emergency Response.* Link.; World Bank. 2019b. *Strengthening Preparedness and Critical Emergency Infrastructure.* Link.; World Bank. 2018. *Strengthening Disaster Risk Management Project.* Link.

101 World Bank and European Commission 2021b.

102 Dolce, M., E. Speranza, G. De Martino, C. Conte, and F. Giordano. 2021. "The Implementation of the Italian National Seismic Prevention Plan: A Focus on the Seismic Upgrading of Critical Buildings." *International Journal of Disaster Risk Reduction* 62. Link.

interest and utility that are owned or managed by central or local public administration authorities. The buildings included in the national program are selected based on a set of criteria, including the peak ground acceleration (PGA), the number of floors and apartments for multistorey buildings with residential purposes, and the importance category of public interest/utility buildings. These investments serve as models for further modernization and investments through national or EU funds.

**Related to the transport sector, an example for scenario-based criticality analysis with AHP was conducted as part of the abovementioned INFRARISK project in Italy.** A stress test was performed that modeled the effect of low-probability, high-consequence seismic hazard events and the associated earthquake-triggered landslides, which helped identify the network elements that were most affected by the hazards and thus need to be prioritized when implementing seismic risk reduction measures.[103] In the stress test, both the vulnerability of network bridges and tunnels to earthquakes and the vulnerability of road networks to landslides were considered, which was done by assigning fragility functions to individual network elements according to their structural characteristics. The impact of the earthquake scenarios was measured in both direct costs (the network repair costs) and indirect losses (the disruptions to the transportation system and network users, with traffic analyses conducted through the use of NEXTA traffic simulation software). The case study provides an integrated approach to hazard assessment and emphasizes rare low-frequency hazard events, which could lead to significant impacts on critical infrastructure and are thus important to be carefully modeled and analyzed.

**Another relevant example of risk-based criticality analysis in the transport sector was carried out as part of the SYNER-G project in Italy which later informed related case studies in Austria, Greece and Italy.**[104] A connectivity analysis with prioritization given to main road segments and bridges collected data at the suburb level. Secondary roads, minor bridges, inactive landslides areas, and dead ends were the least prioritized and hence excluded from the study. The data reduction process removed irrelevant elements at the subnational level and established a concise road network that includes 2,861 nodes, 5,970 edges, and 2,089 active landslide areas. The result of the analysis was measured in terms of both simple connectivity loss and weighted connectivity loss. As for the affected infrastructures within the network regions, health care facilities were prioritized. Hence, the travel disruption and increase in minimum travel time to hospitals due to seismic hazards were modeled and quantified as a part of the analysis. The methodology and the data reduction process used in the study provide a prioritization framework for analyzing complex transportation systems (a combination of roads, highways, bridges, and so on), which may be applicable to major road networks and intra-system infrastructures at the country or international level. The methodology has eventually been applied and validated in seven case studies in Austria, Greece, and Italy.

## DROUGHT

**Slow-onset disasters have complex causes, are extremely difficult to predict, and necessitate a multidimensional and long-term approach.** According to global research, high-income countries are barely affected by moderate droughts; only extreme events have the ability to reduce economic growth by about 0.3 percentage points; in the low- and middle-income countries, the impact can be double as high.[105] Due to a drought's progressive onset and lack of immediate and visible impacts, the awareness and risk perception are often lower compared to rapid-onset disasters. Droughts are nonetheless characterized by compound social, economic, and environmental impacts. Effective drought management therefore requires coordination

103 Clarke, Corbally, and Obrien 2016.

104 Pitilakis et al. 2013. SYNER-G: Systemic Seismic Vulnerability and Risk Assessment of Complex Urban, Utility, Lifeline Systems and Critical Facilities - Methodology and Applications. Link.

105 Zaveri, E. D., R. Damania, and N. Engle. 2023. D*roughts and Deficits: The Global Impact of Droughts on Economic Growth*. Policy Research Working Paper 10453, World Bank, Washington, DC, USA. Link.

among a variety of actors, including from water, agriculture, environment, health, and socioeconomic sectors. It demands investments in vulnerability assessments, monitoring and early warning systems, water-related infrastructure such as irrigation, change in agricultural practices and cultivation of drought-resistant crops, raising awareness about water conservation, and strong community engagement and participation. Considering the complexity and multitude of elements, an MCA approach often seems a natural fit to prioritize DRM investments.

**Several initiatives at the EU level are dedicated to drought hazard and aim to advance the knowledge and available methodologies to assess risks and prioritize investments.** First, the JRC PESETA IV project seeks to enhance the understanding of the environmental and economic outcomes of climate change, by analyzing climate change projections from multiple climate impact models. The project encompasses various sectors that have significance for both society and the natural world, including areas like freshwater resources, agriculture, and coastal regions. Second, the European Drought Risk Atlas[106] presents a conceptual and quantitative approach to drought risk for interconnected systems such as agriculture, water supply, energy, riverine transport, freshwater, and terrestrial ecosystems. The atlas supports the development and implementation of drought management and adaptation policies and actions. Third, the European Drought Observatory (EDO)[107] is a service portal created by the JRC and contains information, graphs, and time series about drought conditions at the European level. The monitoring of droughts is based on the analysis of a series of indicators, representing different components of the hydrological cycle (for example, precipitation, soil moisture, reservoir levels, river flow, groundwater levels) or specific impacts (for example, vegetation water stress). Fourth, the EDORA project[108] widens the scope of the EDO portal by producing a detailed drought impacts database; developing and testing a methodology to assess drought risks in connection to multiple sectors, also considering future scenarios; and compiling relevant information in a drought risk atlas at the EU-27 level.

**While several institutions are working on advancing the knowledge around drought risk monitoring and modeling, not as many existing case studies deal with the prioritization of drought investments.** The prioritization framework for Bulgaria and Greece covered drought as part of their wider NDRMPs—likewise, the abovementioned fire hazard network criticality analysis for the South of France. The EPIC Response Framework[109] considers floods and droughts not as independent events but rather as different ends of the same hydro-climatic spectrum that are inextricably linked.

## EXTREME HEAT

**Like drought, extreme heat is another highly complex phenomenon which requires the employment of interdisciplinary approaches.** The main challenge dealing with this hazard is the absence of universally agreed metrics and thresholds for defining and measuring extreme heat events, which means that reliable and comparable data on historical heat events are hardly available. Additionally, the determination of future trends is highly unpredictable due to spatial variability in view of climate change. Extreme heat is characterized by many interacting factors, including meteorological conditions, UHI effects, population vulnerability, and adaptive capacity of citizen groups. Extreme heat risk is furthermore a non-static risk and instead changes over time due to climate variability, urbanization, land use changes, and other socioeconomic factors. Like drought, the public perception of extreme heat as severe risk is rather comparatively low due to the slow onset and absence of visible immediate impacts.

106 Rossi et al. 2023. *European Drought Risk Atlas.* JRC135215. Publications Office of the European Union, Luxembourg. Link.
107 See EDO website for more information. Link.
108 Launched by the EC in 2021, see JRC website for more information. Link.
109 World Bank. 2023a. An EPIC Response: Innovative Governance for Flood and Drought Risk Management. Link.

**In Italy, an integrated approach between participatory planning and the methods social MCA was applied to guide the city government of Catania to implement a new city greening and resilient development program.** To reduce heatwaves and other effects of climate change, the municipal administration launched a series of climate adaptation programs, including the planning and implementation of new GIs and oriented management of public green areas. To help prioritize the interventions during the GI planning, an integrated approach based on the city 'eco-social-green' model was used. Through a combination of participatory planning (based on the establishment of the focus groups with local stakeholders, operators, and citizens interested in the issue) and the NAIADE[110] method, social opinions were collected, and acceptable options were identified for the city government. The interventions were evaluated according to multiple criteria, including environment, social, climate, economic, landscape, and health safety. The assessment provides a multidisciplinary contribution to the planning and development of green areas in the city, as it integrates ecological, social, and economic values and the opinions of different stakeholders among social groups, places, and temporal dynamics.[111]

**For citywide application of green and white solutions that tackle the UHI effect, BCAs are often used to examine the economic sense and feasibility of different adaptation options and help policy makers make prioritization decisions, as demonstrated by a study in cities of Austria.** The study applied a scenario-based approach using an urban climate model to assess the benefits and costs of white (increased reflectivity of sealed surfaces) and green measures in three small- to medium-size cities in Austria: Mödling, Klagenfurt, and Salzburg. The result of the study shows positive net benefits and BCRs ranging from 1.27 to 2.68 for a combination of white and green measures for the three cities, with benefits including reduced heat-related mortality, morbidity, productivity loss, and numerous urban ecosystem services. At the same time, it also shows higher benefits for combined and green measures, even though such measures have higher implementation costs. The approach provides solid economic grounds for prioritizing implementations and policies in line with the adaptation scenarios.[112] The results were well received by city officials and urban planners in the three cities of this project, and strategies for adapting to the UHI effect were under consideration.

The TDR framework was used to examine the benefits and costs of hypothetical citywide interventions in Vienna to mitigate UHI effects and prioritize future investments.[113] Four types of green and white solutions were assessed, and the result shows positive net benefits for most of the solutions. While green solutions yielded positive BCRs (BCR 1.78–1.79, NPV €1.6–3.2 billion, ERR 78–79 percent depending on the solutions), small or no net benefits were found for green roofs with white solutions (BCR 1.03, NPV €300 million, ERR 2.90 percent) and combined green-white interventions with smaller coverage of green roofs (BCR 0.82, NPV –€2 billion, ERR –18.49 percent). This is due to the relatively low cost and high environmental co-benefits of green solutions, subject to the case of Vienna. Therefore, the result of the study could be applied within the country's context and used to prioritize investments between the choice of green and white solutions for UHI effect mitigation.

110 NAIADE = Novel Approach to Imprecise Assessment and Decision Environments, for the Multi-Criteria Social Assessment also known as Social Multi-Criteria Evaluation (SMCE).
111 Sturiale and Scuderi 2019.
112 Johnson et al. 2020. "A Cost-Benefit Analysis of Implementing Urban Heat Island Adaptation Measures in Small- and Medium-Sized Cities in Austria." *Environment and Planning B: Urban Analytics and City Science* 48 (8). Link.
113 World Bank and European Commission 2021a.

## Lessons Learned from the Existing Case Studies

**Overall, the various examples highlight the importance of using evidence, knowledge, and the right analytical tools to promote investments prevention and preparedness.** While specific challenges and solutions may vary across different disaster types and regions, there are common principles that underpin effective risk reduction efforts which are key for prioritizing investments. Across the various examples, the following common threads and lessons have emerged:

1. *Trade-offs and prioritization.* In resource-constrained environments, decision-makers often face trade-offs when prioritizing investments. MCA, participatory approaches, criticality analysis, and BCA were commonly applied across the reviewed and indeed have helped to identify the most effective and cost-efficient interventions.

2. *Interdisciplinary approach.* Dealing with complex hazards and risks, whether related to floods, wildfires, seismic activity, droughts, or extreme heat, often requires interdisciplinary approaches. Collaboration between various sectors, including meteorology, engineering, environmental science, public health, and social sciences, is crucial for effective DRM.

3. *Context matters.* Solutions and strategies for DRM are context dependent. The specific geographic, climatic, economic, and social conditions of a region or city greatly influence the choice and effectiveness of interventions. The engagement of a wide range of stakeholders can help capture the specificities of the local/national context.

4. *Data and information*. Reliable data, including historical records, comprehensive risk assessments, and early warning systems, are fundamental for informed decision-making in DRM. However, data availability and quality can vary, posing challenges in some cases. Investments in collection methods and improving quality of data are thus important.

5. *Risk assessment.* Comprehensive risk assessments, whether through probabilistic modeling, scenario analysis, or vulnerability assessments, are a critical step in prioritizing investments and interventions. Understanding the likelihood and potential impacts of disasters informs decision-making.

6. *Complexity and uncertainty.* Many disasters, such as floods, wildfires, and droughts, are characterized by complexity and high degrees of variability. Climate change further amplifies these challenges. Flexibility and adaptability in risk management strategies are essential to account for changing conditions and unforeseen events.

7. *Long-term planning.* DRM requires a long-term perspective. Investing in resilience-building measures, such as infrastructure improvements and community capacity building, is essential for sustainable risk reduction.

8. *Governance and policy frameworks.* Strong governance structures, regulations, and policies play a critical role in DRM. Coordinated efforts at the local, national, and international levels are necessary for effective risk management. Exploring cross-border issues may help exploit positive or prevent negative spillover effects.

9. *Community engagement.* Engaging with local communities and stakeholders is a common thread in effective DRM activities. Local knowledge, participation, and ownership in decision-making contribute to more resilient and sustainable solutions.

10. *Public perception and awareness.* The perception of risk among the public can vary, and awareness of slow-onset disasters like droughts and extreme heat is often lower due to their less visible immediate impacts. Effective risk communication and awareness-raising are essential for saving lives and costs.

# 4. Applying Prioritization Tools: Highlights from Case Studies

**This chapter presents five new case studies which have applied different analytical tools for prioritization to show how to adopt focused and smart decision-making. Considering different hazards, sectors, and levels of planning/decision-making,** these case studies focus on rapid and simplified approaches which can be undertaken also in data-poor environments and/or as part of a phased approach. Beyond providing step-by-step guidance, they also provide broader policy recommendations for improving disaster and climate resilience of critical sectors. Case studies are structured in four parts with information about the national context, analysis conducted, findings, and lessons learned/ recommendations.

## KEY TAKEAWAYS

- **Aligned with Chapter 2, the case studies confirm the importance of integrating the following within the prioritization frameworks:** First, integrate disaster risk information and—as much as possible—future climate projections. Second, consider the criticality of networks/services or portfolio of emergency response-related assets. Third, estimate benefits and costs of investing in prevention and preparedness. While specific situation will determine the degree to which these can be integrated, efforts should be made to consider these as much as possible.
- **While different in their nature and context, all case studies strongly underline the feasibility to conduct analytics to support better decisions for investing in DRM.** While there are many data gaps, these case studies demonstrated the feasibility to rapidly collect data and conduct the analysis in a staged/phased approach (including a rapid or simplified initial analysis to start with) whereby the prioritization can be expanded as new information/data become available. By doing so, data limitations cannot be used as an excuse to forgo individual prioritization tools. This also highlights the continuous need to invest in better data generation as well as data/information management and coordination, so that the collected data can be used for multiple purposes and are accessible to a wide array of partners.
- **Across the case studies, there is a notable opportunity and importance of engaging stakeholder and foster collaboration among officials, practitioners, and experts**. While more technical analytics can be driven by experts, stakeholders need to be engaged in the process from the very beginning to ensure ownership and needs orientation. Especially in view of the prioritization frameworks, consultations and stakeholder input on decision criteria and their weighting are essential, for example, to better understand and evaluate the importance of a CP infrastructure for a given area or as part of a network, a government's willingness to address identified weaknesses, or other strategic preferences and competing priorities. Understanding these factors helps increase the likelihood that identified DRM investments are smart, focused and brought to fruition.

- **The Bulgaria case study demonstrates how to benefit from MCA and supplemental hazard-specific analysis for national-level prioritization.** The case study built on existing prioritization of DRM, which was done under the NDRMP, based on an MCA in combination with a scenario-based approach. Through the case study, additional information on heat and wildfire risk was considered and KPIs were used to facilitate the quantification of effectiveness of several risk reduction and resilience enhancement measures. This approach can further enhance the prioritization of measures in a quantitative and objective context. This example also shows how countries define KPIs to help them track progress in achieving national DRM objectives, ensuring links with other high-level strategies/goals such as the EU DRGs. *This approach can be highly relevant to UCPM members facing heat and wildfire risks.*
- **The Croatia case study utilized a rapid portfolio-level vulnerability assessment in combination with the TDR analysis of benefits and costs.** The example shows how rapid, yet robust analysis and prioritization tool help quantify seismic risks within the portfolio of CP/emergency response buildings and the expected benefits to inform prioritization. The analysis considers seismic risk and energy efficiency interventions as part of a 'smart' approach to investing in risk reduction and CCA. [114] *This approach can be highly relevant to UCPM members with exposed/vulnerable CP infrastructure to disaster and climate risks.*
- **The Portugal case study analysis employed a social vulnerability and BCA approach combining expert knowledge and geographic data analysis to prioritize villages for the "Safe Village, Safe People" (SVSP) programs based on various factors influencing wildfire risk.** It also conducted a comprehensive BCA to assess the program's economic viability under different scenarios. The SVSP program is a critical initiative to enhance wildfire risk awareness among rural populations in wildfire-prone areas. This methodology served as a robust framework for making informed decisions about resource allocation and wildfire risk reduction in Portuguese civil parishes. Overall, the case study demonstrated that prioritization, adaptability, and thorough analysis are crucial elements in addressing wildfire risks and highlighted the benefits of investing in high-risk areas, promoting collaboration, and considering demographic and economic shifts in risk reduction strategies. *This approach can be highly relevant to UCPM members facing wildfire risks/having in place similar risk reduction/prevention programs or planned to roll out such programs.*
- **The Romania case study illustrates criticality prioritization tool, focusing on transport as a critical sector.** Using a multi-criteria and criticality analysis to evaluate Romania's transport networks, the case study shows that prioritization decisions can be informed through improved understanding about transport segments that are most vulnerable to specific hazards and most critical in terms of service delivery. The study identified those transport segments that are both critical and flood exposed, critical but not flood exposed, or not critical but highly flood exposed. This rapid analysis generates information which is fundamental for carrying out targeted and smart investments and making good use of public funds. The case study also provides suggestions for future research considering future climate scenarios. *This approach can be highly relevant to UCPM members with critical assets at flood risk/at risk from other or multiple natural hazards.*
- **In Croatia's second case study, the R2R methodology was used to conduct a rapid, systematic, and data-driven self-assessment of national- and city-level capacities.** The multi-hazard self-assessment considered five functional components of traditional emergency preparedness and response capacities (a) legal and institutional framework, (b) personnel, (c) facilities, (d) equipment, and (e) information. Results were generated within days and give an overview of key strengths and

114 In line with EC. 2021e. *Technical Guidance on the Climate Proofing of Infrastructure in the Period 2021–2027.* Link.

weaknesses within national- and city-level preparedness and response systems, which can directly inform the prioritization of focused investments. *This approach can be highly relevant to UCPM members seeking a rapid analysis and understanding of key gaps in preparedness and response that can be the focus of further actions and investments.*

- **Linked to the exposure analysis presented in Chapter 1, country-specific maps were created for the case study countries of Bulgaria, Croatia, Portugal, and Romania.** These maps show the distribution of emergency response-related assets and hazard levels based on available EU-wide hazard data, which were augmented with national records. These maps can be helpful in identifying areas that are exposed to high levels of multiple hazards. By providing a visual representation of the distribution of assets and the level of hazard they face, these maps can assist decision-makers in prioritizing areas for further analysis and investment. By focusing on assets that are exposed to high levels of multiple hazards, decision-makers can develop effective strategies to manage the risks associated with these hazards and minimize potential losses.

## Bulgaria - National-Level Prioritization and Use of MCA and KPIs

**The case study built on existing prioritization of measures in Bulgaria, which was done under the NDRMP and was based on an MCA in combination with a scenario-based approach.** [115] The Bulgaria case study generated new information by focusing on extreme heat and wildfires. The overarching objective was to bolster decision-making based on empirical evidence, to provide insights for policy planning and subsequent in-depth assessments, and to facilitate prioritization of intervention with the aim of reducing risk, enhancing resilience, and improving efficiency. The analysis lays out steps and highlights applicable methodologies to facilitate prioritization of DRM investments in alignment with the EU's legislative frameworks, including the risk scenarios and DRGs, and EC initiatives and strategies on CCA adaptation.

**This case study also makes a link between disaster and climate resilience through the use of risk information and KPIs to help evaluate the effectiveness of considered measures for extreme heat and wildfires.** The case study is of value for decision-makers who approach prioritization of investments from both a top-down and a bottom-up perspective and shows how national DRM and CCA strategies can be used in combination with risk analytics to develop and prioritize specific pathway adaptation measures. The KPIs identified in this study are typical and exemplary for prioritization at the national level and could also be applied by other countries for monitoring of national DRM plans and strategies. **These analytical tools can be highly relevant to UCPM members facing heat and wildfire risks.**

### BACKGROUND

**Bulgaria is confronted with an anticipated rise in future air temperatures as a consequence of climate change.** The country is particularly vulnerable to various hazards exacerbated by this warming trend, with extreme heat, wildfires, and droughts posing significant threats. On average, the country currently experiences eight days of extreme heat per year. However, by 2050, this number is projected to rise to between 14 days (under RCP 4.5) and 18 days (under RCP 8.5). This increase in extreme heat days is expected to affect urban centers due to the UHI effect. Based on statistical analysis, climbing extreme temperatures will lead to a rise in the annual average excess mortality, alongside morbidity which will also

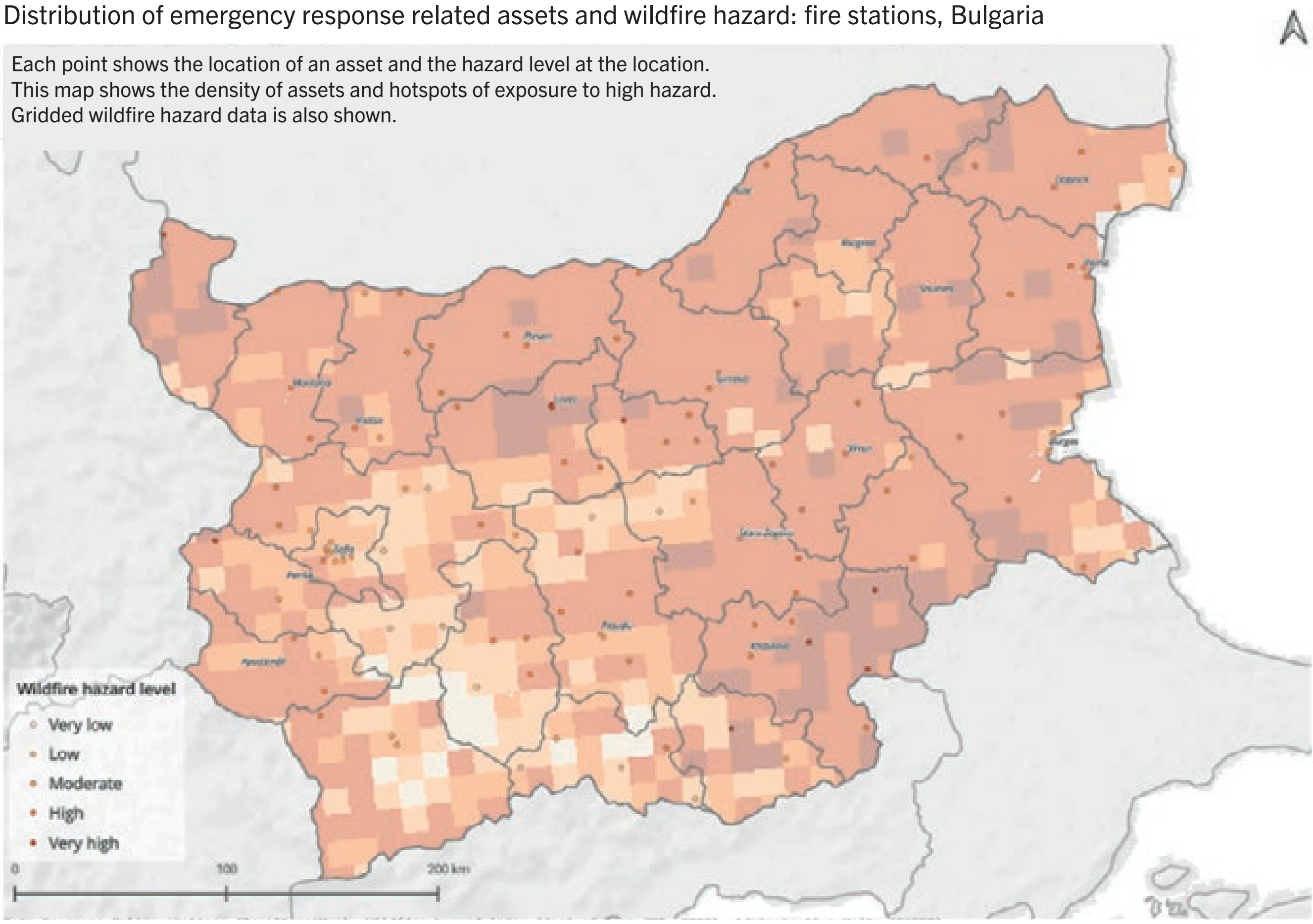
115 Conducted as part of Reimbursable Advisory Services Agreement on Accelerating Resilience to Disaster Risks between the Ministry of Interior of the Republic of Bulgaria and World Bank (P170629).

be affected significantly. Although the available data on disaster damage and loss in Bulgaria are fragmented and incomplete, an average of 600 forest fires, covering an area of 10,000 ha, are reported annually. This represents a significant increase since 1990, with further escalation in frequency and magnitude predicted in the future due to climate change.

**The EU-wide exposure mapping presented in Chapter 1 revealed that most of Bulgaria's emergency-related assets (64 percent, 79 of the country's 124 assets in the available data set) are in areas of high wildfire hazard,** especially in the northern, eastern, and central regions of the country as well as in a small strip to the very west. Only for municipalities in the southeast the exposure is generally slightly lower, as shown in Figure 23. Of course, being in areas of high wildfire is advantageous for a quicker response to wildfire and poses a risk to that response if assets are affected. Due to the coarse resolution of wildfire hazard data available for the analysis, this EU-wide analysis cannot inform on the exposure or risk of damage/service disruption at specific assets. It does, however, inform on the exposure of these assets not only to wildfire but also to earthquake, landslide, and flood: 43 percent of fire stations in Bulgaria are exposed to high levels of two hazards.

**Figure 23.** Distribution of fire stations and wildfire hazard in Bulgaria

Distribution of emergency response related assets and wildfire hazard: fire stations, Bulgaria

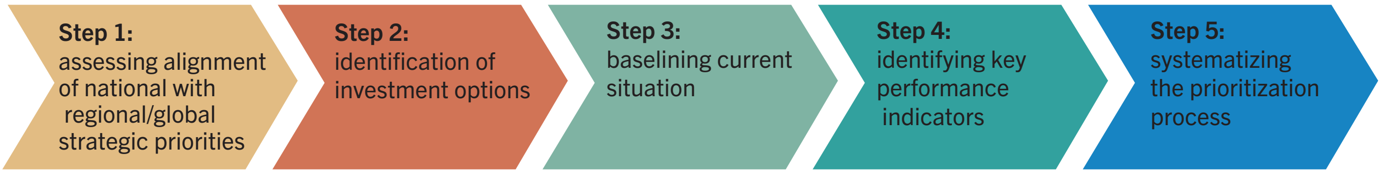



*Source:* World Bank, as part of EU-wide exposure analysis.

## STEPS IN THE ANALYTICAL PROCESS

**The case study methodology** comprises five steps:

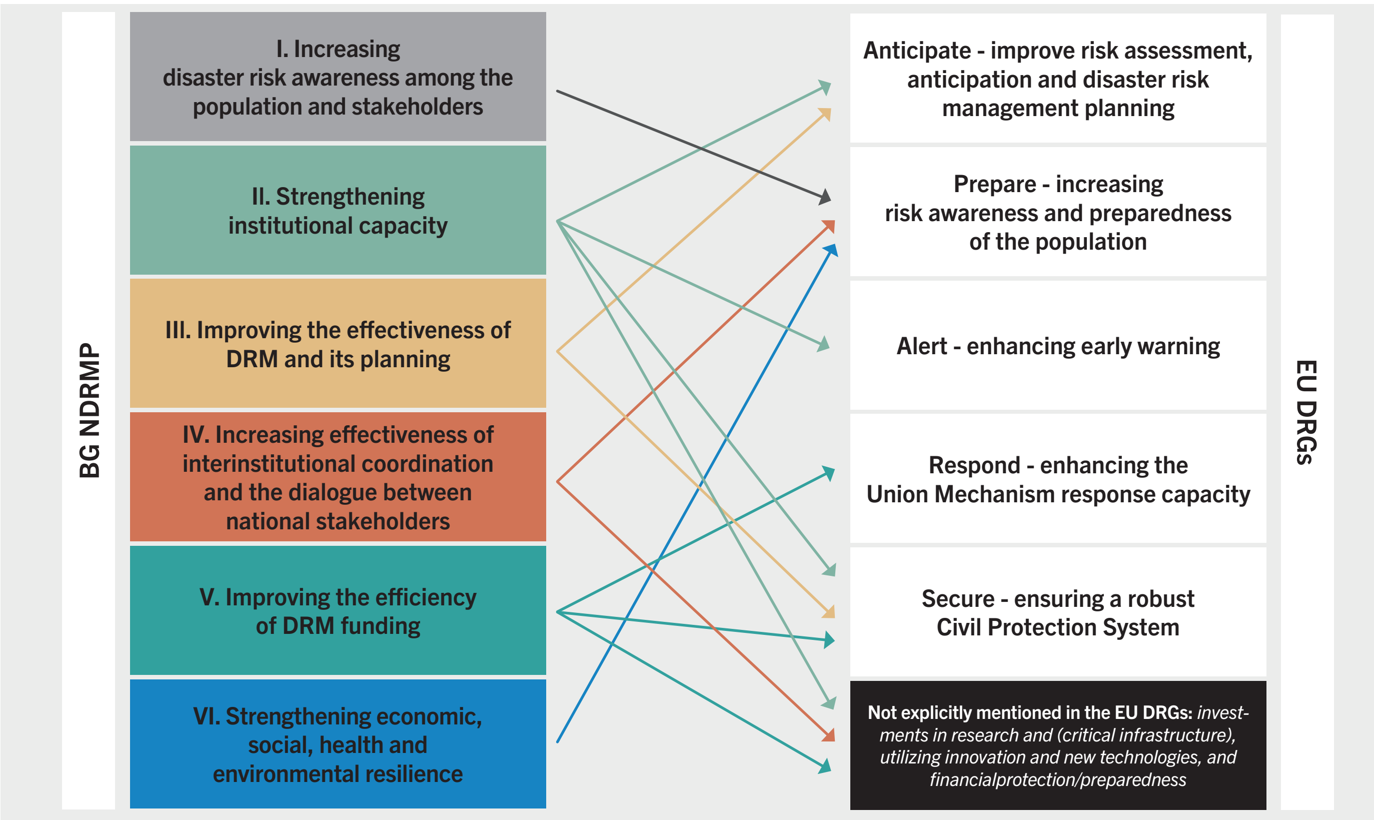
**Figure 24.** Five-step process using Key Performance Indicators




**Step 1: Assessing alignment of national with international priorities.** Bulgaria's DRM decisions are guided by the National Disaster Risk Reduction Strategy for 2018–2030 and associated Action Programs, including the NDRMP. Its individual priorities are analyzed and compared with priorities of various frameworks such as the EU DRGs and the SFDRR to understand overall context and links.

**Bulgaria's National Disaster Risk Reduction Strategy for 2018–2030 and associated Action Programs are well aligned with the EU DRGs (Figure 25).** Especially, Bulgaria's first two strategic priorities on understanding and increasing awareness about risks and strengthening governance and institutional capacities already cover most priorities highlighted by four of the five actions of the EU DRGs. The remaining aspects of the EU DRGs find holistic reflection in Bulgaria's other priority areas. In summary, the analysis performed in Step 1 found that Bulgaria's National Disaster Risk Reduction Strategy and Action Programs not only align harmoniously with the EU DRGs but also surpass them in ambition and specificity across various dimensions. The nation's strategic vision exemplifies a proactive and comprehensive approach to DRR, emphasizing the importance of understanding, preparedness, innovation, and financial protection in building a resilient and disaster-ready society.

**Figure 25.** Linking Bulgaria's National Disaster Risk Reduction Strategy 2018–2030 with EU DRGs




*Source:* World Bank.

**Step 2: Identification of investment options.** This part of the analysis focuses on the process of identification, definition, description, and categorization of DRM investment options (including no-regret and/or low-regret actions) considering short- and medium-term horizons. This includes a review of the state of the art and state of practice of the considered measures with reference to the relevance, applicability, and ease of implementation of the considered measures to the Ministry of Interior's Directorate-General (DG) Fire Safety and Civil Protection (FSCP) and other identified relevant stakeholders. This method evaluates measures based on various criteria, including the importance of addressing national risk(s) effectiveness in reducing risk, economic efficiency, financial and social sustainability, current implementation capacity, and urgency. In this context, it is possible to prioritize potential measures quantitatively and qualitatively within and across different risk categories, considering the impact with respect to the EU DRG's and enabling a comprehensive assessment.

**Step 3: Baselining current situation.** The next step concerns baselining the 'current' situation, in terms of KPIs related specifically to extreme heat and wildfire (for example, vulnerability to heat exposure, heat-related mortality and morbidity, and loss in productivity), derived from available national and international data sources.

**Considering extreme heat the MCA focused on criteria relating to, for example,** (a) the establishment of heat early warning system and awareness campaigns to provide the public with information concerning the health effects of extreme heat; (b) development of national rules/recommendations for changes in working hours of schools/universities, institutions, and outdoor work in cases of extreme heat; (c) development of a Heat Health Action Plan; (d) development of a UHI strategy; (e) establishment of a heat protection strategy for employees; (f) establishment of an automatic data collection system for heat-related excess mortality cases; (g) establishment of guidelines for the preservation of current natural spaces in urban environments and so on; and (h) evaluation of green, grey, and/or hybrid solutions.

**For wildfire risk reduction and intervention prioritization, criteria considered included** (a) conducting education, communication, and public outreach activities to reduce the risk of forest fires caused deliberately or by negligence by humans; (b) equipping and training fast-response firefighting groups in the forest territories related to the forest enterprises and the voluntary groups—securing funding for the purchase of new machinery and equipment and maintenance of existing ones for extinguishing forest fires of the teams of DG FSCP; (c) building a national system for rapid fire detection and response to fires and other natural calamities in forest ecosystems; (d) improving the plans for protection of forest territories from fires based on the current and future versions of the mapping of forest fire risk at country and subnational level, building on improved knowledge on fire risk, potential fire intensity, and other modeling; (e) implementing activities that limit the chances of fires and fire spread (fire mitigation measures) such as fire stripes, fire and fuel breaks, roads, water reservoirs, thinning of young dense plantations, creation of forest stripes with species with lower burnability; and (f) promoting faster recovery after large fires by afforestation—planning and creating defensible spaces and special measures for reducing the risk of fires in WUIs and so on.

**Step 4: Identifying KPIs.** The case study demonstrates procedures to evaluate the effectiveness of considered DRM measures on KPIs with respect to the baseline, thereby facilitating identification of risk reduction strategies for investing in DRM as well as CCA.

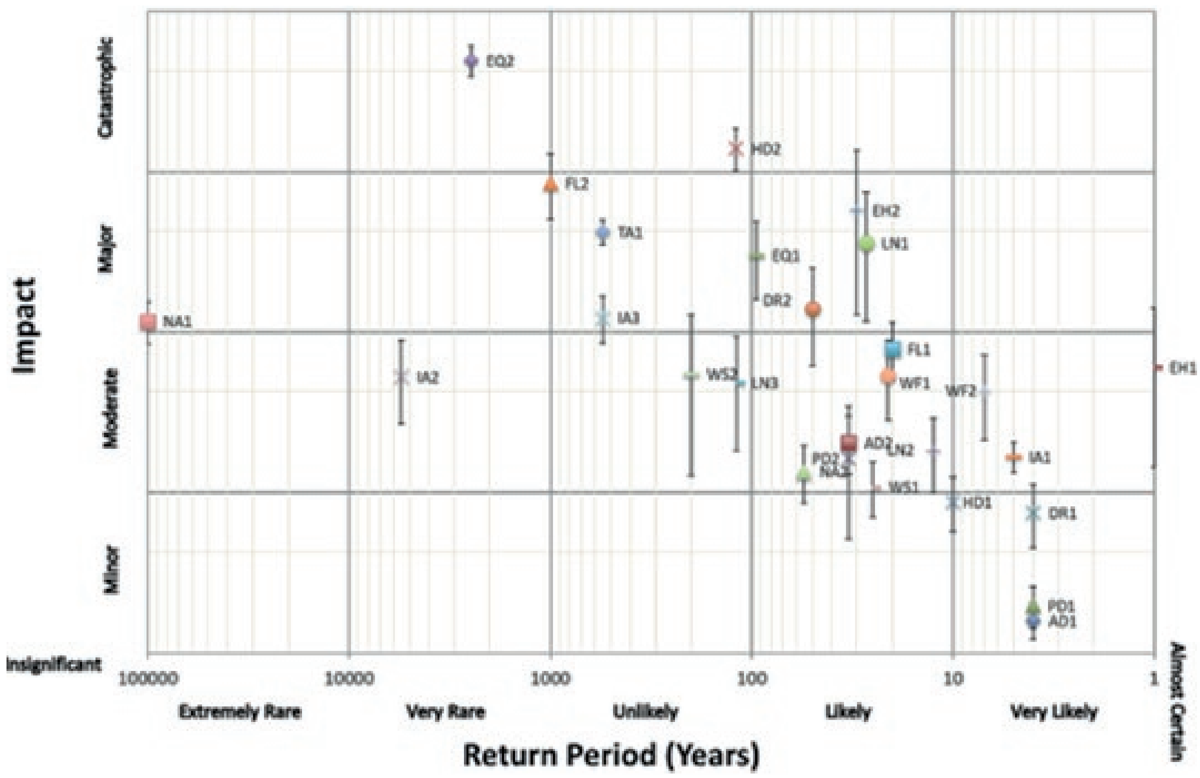
A comprehensive set of KPIs ensures a holistic evaluation of measures, enabling decision-makers to make informed choices in mitigating the challenges posed by extreme heat and wildfires. The KPIs could and should be mapped against the risk evaluation criteria centered around (a) effectiveness, (b) efficiency, (c) sustainability, (d) capacity, and (e) urgency. In this way, their contribution to the overall prioritization score can be evaluated.

Via definition of KPIs, the effectiveness of alternative measures may be analyzed and quantified in terms of benefits and costs and further nuanced to consider risk reduction and resilience enhancement, thereby facilitating a prioritization of measures in a quantitative and objective context. The following list of KPIs can be useful in view of extreme heat and wildfire hazards:

- Change in UHI index (%)
- Increase in productivity/economic activity and/or decrease of morbidity among workforce
- Increase in energy consumption and/or increase in blackout events (%)
- Population forced to evacuate (short term) or migrate (medium to long term) (%)
- Population reached by heat-related messaging/ early warning (%)
- Urban Greenery: percentage of land area (PLAND), number of patches (NP), patch density, largest patch index (LPI), landscape shape index (LSI), and so on
- Occupancy of emergency departments, percentage available capacity in ED's during heatwaves.

**Step 5: Systematizing the prioritization process.** The last step aims at developing a systematic process for risk-based prioritization with respect to the considered KPIs. The results are correlated in line with the EU DRGs. Figure 26 illustrates the computed impact and likelihood of major risks in Bulgaria as computed for the NDRMP. EH1 and EH2 refer to scenarios associated with extreme heat, namely 28.7–34.0°C for 27 days (EH1, return period: 1 year) and over 34°C for 20 days (EH2, return period: 30 years), while WF1 and WF2 referred to wildfires in Kresna (WF1, return period: 21 years) and Topolovgrad (WF2, return period: seven years), respectively. The uncertainty around the impact of the considered risk is also illustrated. Significantly, via the quantification of risk in an objective sense, those measures which have the greatest impact on the risk profile can be prioritized in line with the criteria considered and weighted in the MCA analysis. **Correlated to this, resilience enhancement measures can be prioritized in line with the EU DRGs.**

**Figure 26.** Diagram showing impact and likelihood of major risks in Bulgaria



| Scenario abbreviations | | | |
|---|---|---|---|
| AD1 | Animal infectious disease - Minor losses (4y) | IA2 | Industrial accident - Liquefied petroleum gas storage plant (>1,000y) |
| AD2 | Animal infectious disease - Major losses (33y) | IA3 | Industrial accident - Chlorine storage facility (>100y) |
| DR1 | Droughts - Precipitation 1,123 mm for 2 years (4y) | LN1 | Landslides - Danube coast (27y) |
| DR2 | Droughts - Precipitation 2,500 mm for 5 years (50y) | LN2 | Landslides - Asenovgrad - Smolyan Road (12.5y) |
| EH1 | Extreme heat - 28.7-34°C for 27 days (1y) | LN3 | Landslides - Black Sea coast (119y) |
| EH2 | Extreme heat - > 34°C for 20 days (30y) | NA1 | Nuclear accident - Kozloduy NPP (100,000y) |
| EQ1 | Earthquakes - Plovdiv, M5.5 (95y) | NA2 | Nuclear accident - Industrial source of ionizing radiation (55y) |
| EQ2 | Earthquakes - Sofia, M6.9 (2,475y) | PD1 | Plant infectious diseases - Minor losses (4y) |
| FL1 | Floods - Sofia, urban (20y) | PD2 | Plant infectious diseases - Major losses (33y) |
| FL2 | Floods - Varna, urban + coastal (1,000y) | TA1 | Railway accident - Burgas port area (>100y) |
| HD1 | Human infectious disease - Influenza pandemic (10y) | WF1 | Forest fires - Kresna (21y) |
| HD2 | Human infectious disease - Coronavirus pandemic (>100y) | WF2 | Forest fires - Topolovgrad (7y) |
| IA1 | Industrial accident - Explosives facility (>1y) | WS1 | Windstorms - > 28.9 m/s (25y) |
| | | WS2 | Windstorms - > 32.7 m/s (200y) |

*Source:* World Bank 2021.

## SUMMARY OF FINDINGS

**The case study from Bulgaria illustrates the benefits derived from the application of MCA and additional hazard-specific analysis in the prioritization of national-level measures.** Using the established MCA prioritization framework within the NDRMP, this case study unveils outcomes generated through the integration of a scenario-based approach. This comprehensive analysis goes beyond the existing prioritization by incorporating valuable insights into the risks associated with heatwaves and wildfires. The integration of KPIs emerges as a crucial element, playing a central role in objectively quantifying the effectiveness of diverse measures aimed at risk reduction and resilience enhancement. The methodology presented provides a structured and quantitative framework for prioritizing measures, demonstrating how countries can systematically enhance their strategies. The case underscores the significance of clearly defined KPIs in tracking the progress toward achieving national DRM objectives, establishing vital connections with broader initiatives such as the EU DRGs. This approach holds particular relevance for members of the UCPM facing challenges linked to heatwaves and wildfire risks, providing a valuable model for focused decision-making in DRM.

**The calculated impact and likelihood of significant risks in Bulgaria were showcased,** as computed within the framework of the NDRMP, as depicted in Figure 26. The evaluation also addressed the uncertainty associated with the impact of identified risks. Significantly, through the objective quantification of risk, the prioritization of measures with the most substantial impact on the risk profile becomes feasible. This process aligns with the predefined criteria and weights in the MCA.

**Within the context of the MCA, measures underwent assessment based on their significance in addressing national risk(s), efficacy in risk reduction, economic efficiency, financial and social sustainability, existing implementation capacity, and urgency of need.** The overall prioritization score for each measure was derived through a weighted combination of the aforementioned criteria. Each criterion was assigned a score ranging from 1 to 3, where 1 denoted the lowest priority and 3 indicated the highest priority for a given measure. This simplified approach enabled a combined quantitative and qualitative prioritization of potential measures within and across categories of risk. The approach may be further nuanced, as required, emphasizing, for example, the significance of the risk such that hazards with a catastrophic impact become prioritized, even where available options are not particularly efficient or sustainable, as considered appropriate. An additional consideration may be given to identifying prioritization based upon consideration of where maximum consequence reduction can be achieved through implementation of relatively simple measures. In this regard, it is probable that priority will be given to those scenarios with high levels of likelihood. Finally, it is possible to consider an aggregation or hybrid of the outlined strategies in arriving at risk-based prioritization of actions.

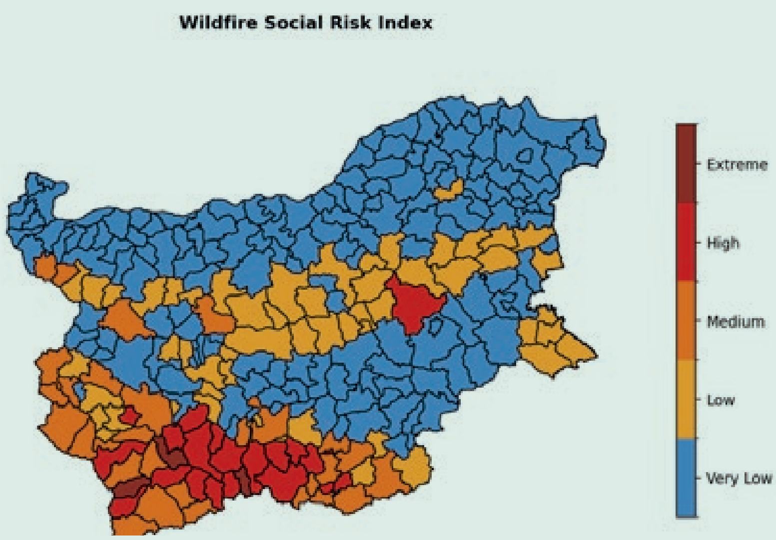
**Integration of new data and information over time.** The approach of applying KPIs for prioritization of investment options also facilitates the integration of new and updated data and information, especially related to future climate conditions. This flexibility allows the integration and/or update of individual or a set of KPIs without having to question the prioritization framework's overall design. An example of how to integrate additional layers of risk information is presented in Box 15.

**BOX 15.** EXAMPLE OF INTEGRATING FURTHER LAYERS OF DATA

A rapid wildfire analysis conducted as part of this study can be used to further enhance prioritization of wildfire specific actions, as it considers climate change projections in risk modeling and combines social vulnerability and coping capacity to understand specific regions that may experience underinvestment. By incorporating future climate projections, such as increased temperatures and altered precipitation and wind patterns, analysts and planners can better anticipate changes in wildfire distribution, frequency, and intensity. Additionally, considering annual average losses for the entire country provides a more comprehensive understanding of the economic losses due to wildfires, beyond localized, scenario-based impacts. The Wildfire Social Risk Index (Figure 27) can provide insight into higher-risk areas that have lower firefighting capacity and higher social vulnerability. This broader perspective allows decision-makers to prioritize regions with the highest potential for severe wildfires and low firefighting capacity, thereby allocating resources more effectively. Furthermore, by factoring in the potential effectiveness of intervention strategies, the analysis can identify areas at scale where proactive measures can mitigate future risks effectively. Ultimately, integrating climate change predictions, comprehensive loss assessments, and intervention effectiveness analysis enables a more nuanced and informed wildfire risk prioritization process, leading to more strategic allocation of resources.

Considering Figure 27, the southern region of Bulgaria faces a combination of high wildfire risk, high social vulnerability, and lower capacity to respond to wildfires, along with an elevated risk extending across the central part of the territory. Smart investments in strengthening wildfire action are essential to protect these areas. By evaluating the potential impacts, decision-makers can strategically distribute resources to enhance efficacy of measures to ensure that high-risk areas are adequately safeguarded. The geographic distribution of risk allows decision-makers to comprehend the specific nature of the threat, its potential evolution, and the areas requiring prioritized attention in the immediate, medium-term, and long-term planning.

**Figure 27.** Bulgaria - example of wildfire social risk index




*Source:* *World Bank based on CIMA analysis.*

### LESSONS LEARNED AND RECOMMENDATIONS

**For Bulgaria and other countries.** The novelty of this analytical approach lies in its capacity to measure the impact of CCA measures using defined KPIs,[116] facilitating the planning and prioritization processes at the national level. Many of the selected KPIs exhibit correlations, emphasizing the need for prioritization strategies to consider their interrelation and potential co-benefits in terms of both risk reduction and resilience enhancement. The development of a robust decision-making tool enables the prioritization of risk reduction measures with quantifiable impact, setting a commendable standard for national-level prioritization. These methods can serve as exemplars for other countries, aiding in the monitoring of national DRM action plans and strategies or supporting the implementation of the EU DRGs. A comprehensive and reliable data set is crucial for their effective evaluation, underscoring the importance of collecting such data sets. Additionally, these KPIs prove suitable for supporting the operationalization of EU DRGs. Those undertaking a similar analysis in other countries should take into account the following crucial considerations, in addition to the issues pertaining to KPIs presented:

- *Engage a diverse range of stakeholders.* Involve a broad spectrum of stakeholders throughout the prioritization process, establishing transparent communication lines to convey the criteria, process, and results to stakeholders and the general public.
- *Ensure data reliability and up-to-date information*. Ensure the availability of reliable and up-to-date data for the criteria used in the prioritization process. Conduct a comprehensive risk assessment considering multiple hazards, their interactions, and potential impacts.
- *Establish a robust MCA framework.* Develop a transparent and robust framework for MCA, incorporating relevant and weighted KPIs that span economic, social, environmental, and institutional factors.
- *Adopt flexibility in applying prioritization tools.* Acknowledge that priorities and conditions may evolve over time. Develop a prioritization approach that is flexible and allows for regular updates to reflect changing circumstances.
- *Scenario-based approach considerations.* When employing a scenario-based approach, consider a range of events, including climate change projections, population growth, and technological advancements. Evaluate investment options under different scenarios to identify robust and adaptable solutions.

## Croatia - Portfolio-Level Assessment of Emergency Response-Related Assets and TDR approach

**The case study on Croatia shows that using a rapid portfolio assessment to inform plans to invest in critical sector infrastructure.** The assets analyzed in this case study are important lifelines, and in case of their failure to provide services after a major disaster, this would have cascading negative impacts on the population. This kind of rapid analysis relies on simplified data collection and is particularly relevant for data-poor environments. The seismic analysis across portfolio of CP buildings was complemented by the use of the TDR approach to calculate benefits and costs of possible interventions to guide future decision-making toward prioritization of risk reduction and preparedness investments at the sectoral level. **These analytical tools can be highly relevant to UCPM members with exposed/vulnerable emergency response infrastructure to disaster and climate risks.**

116 Note that under EDPP Component 2, climate projections are included to further specify and match the KPIs to measures.

## BACKGROUND

**Croatia is in the region of moderate to high seismic hazard, but the building stock is relatively old and poorly maintained.** New buildings (that is, those in compliance with modern building codes) represent only a small percentage of the building stock in Croatia (estimated between five and ten percent).[117] The series of earthquakes in 2020 highlighted the vulnerability of Croatia's public and private infrastructure stock, including critical infrastructure such as hospitals or administrative buildings. Until 1964, when the first building code introduced seismic provisions, buildings were constructed with little to no consideration for seismic shaking—and about one-third of the existing building stock dates from this period. Furthermore, many buildings across the country have not been legalized, meaning that the construction may be inadequate and result in vulnerable buildings which could pose a danger when the next earthquake hits. While the process of rehabilitation/reconstruction is ongoing for recently damaged buildings, there is a large volume of aged public and private building stock which continues to remain vulnerable to the impacts of earthquakes and potentially other hazards as well. Investments in energy-efficient retrofitting are increasing but often lack comprehensive considerations for earthquake resilience, fire safety, and other climate-related impacts like heat resilience, flood-proofing, and wildfire.

**The EU-wide exposure analysis as described in Chapter 1 revealed two significant hotspots when considering emergency response-related assets exposed to one or more high or very high hazards.** The first can be found in and around Zagreb up until the very north of the country, and the second is around Split and across the Split-Dalmatia County. Further concentrations of assets subject to high/very high hazards are found scattered along the Croatian coastlines, including around Rijeka, Zadar, Šibenik, and Dubrovnik (see Figure 28). Multi-hazard exposure is high, for example, 48 percent of fire stations in Croatia are exposed to high levels of two or three hazards. The exposure to multiple combinations varies by asset type. The dominant combination of hazards to which fire stations are exposed is wildfire and earthquake. For health care facilities, exposure also concerns, to a greater extent, landslide, flood, and earthquake.

**Figure 28.** Location and density of emergency response-related assets across Croatia exposed to high levels of multiple hazards


*Source:* World Bank, as part of EU-wide exposure analysis.

117 At the EU level, around 40 percent of buildings were constructed before the 1960s. See EC. iRESIST+ innovative seismic and energy retrofitting of the existing building stock. Link.

**To address challenges, efforts must be made to balance the need for modern infrastructural resilience against the looming climate threats.** Yet, currently, there is no prioritized approach or data within this sector that decision-makers could use to prioritize buildings and types of interventions based on cost-effectiveness, seismic safety, and other CCA-related aspects. This case studies focused on addressing some of the data and information gaps, and feasibility of developing a prioritized approach.

## STEPS IN THE ANALYTICAL PROCESS

**The overall methodological approach follows a standard approach used and applied in several countries across Europe for prioritization of infrastructure investments.**[118] Multiple sources of information were used to assess climate-related risks relevant to these critical infrastructure assets. A major objective was for this analysis to be consistent with approaches taken in other countries in the region while being transparent and replicable to serve as inspiration for other countries in the future. The main criteria for developing this approach were to balance operational practicality with analytical robustness, such that orders of magnitude can be estimated for the selected critical infrastructure assets and subsequently updated and expanded as improved data become available for granular multi-hazard vulnerability analysis. The analysis undertaken for Croatia follows a four-step approach that demonstrates the application of a portfolio-level rapid vulnerability assessments and costing of CCA measures to support initial prioritization of risk reduction and preparedness investments at the sectoral level—building on previous initiatives and providing a basis for future updates and refinements.

**Step 1: Portfolio-based analysis of CP infrastructure.** A portfolio vulnerability analysis of four types of CP infrastructure: (a) county firefighting centers (193), (b) national/county centers (112), (c) firefighting stations in the city of Zagreb, and (d) CP headquarter buildings in the city of Zagreb, with a probabilistic analysis of risk, vulnerability, and exposure of these buildings to seismic hazard.

**As part of the portfolio assessment**, building exposure data across 60+ buildings of emergency response services were collected and analyzed. Like in many other countries, there is no official inventory database in Croatia that includes building material, age, floor area, structural system, and occupancy category of buildings, that is, parameters critical for seismic assessments. There is also no inventory database for the public sector including emergency facilities in Croatia. To fill these gaps, a survey was used to collect information on key building attributes,[119] functional and occupational data, and photos and other documentation on the buildings which can help inform further phases of the prioritization. The information collected was mostly oriented toward informing seismic risk and energy efficiency analytics, but additional information was also considered related to other hazards.

**The seismic hazard model adopted in this study is the 2020 European Seismic Hazard Model (ESHM20).** Exposure model contains buildings characterized by different typologies per the Global Earthquake Model (GEM) taxonomy; vulnerability model was adopted from GEM. The risk analysis used two probabilistic scenarios for 95- and 475-year return periods with replacement costs and annual average losses estimated and a *what-if* scenario event based on the historical earthquake from 1880 in the city of Zagreb.

**Step 2: Additional analysis related to energy efficiency.** Energy performance of the CP/emergency response buildings was analyzed to understand the energy efficiency of the building (energy consumption) and the reduction of $CO_2$ emissions after potential energy renovation. As part of this, relevant data were collected from the National Energy Management

118 Strengthening DRM Project (P166302); Improving Resilience and Emergency Response Project (P168119); Strengthening Preparedness and Critical Emergency Infrastructure Project (P168120); Romania Safer, Inclusive, and Sustainable Schools (P175308).

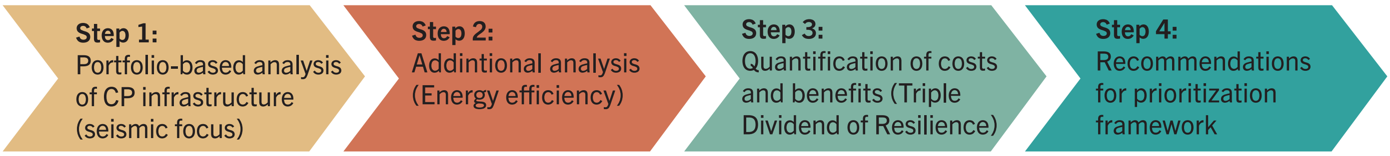
119 The main attributes collected in scope of this study include material of lateral-load system, lateral-load resisting system, period of construction, code level, system ductility, number of stories, building height, building floor area, physical condition/maintenance, shape of building plan, structural irregularities (in plan and in height), roof shape and structure, floor system material and type, and foundation material and system.

Information System (ISGE), noting, however, that from the list of CP/emergency response portfolio buildings, the ISGE database contains data only for about 35 buildings.

**Step 3: Quantification of benefits and costs.** Using a TDR approach, benefits and costs of interventions related to seismic safety and energy efficiency were estimated. The costing considered avoided losses related to people and infrastructure and disruptions. Within the framework, benefits relating to CC and risk reduction were considered and quantified as well, whenever it was possible. The final result is an overview of potential financial costs of a prioritized program focusing on investing in upgrading buildings in an efficient manner.

**Step 4: Recommendations for prioritization framework, including various criteria.** Based on the analysis and collected data, as well as consultations with stakeholders, recommendations of different parameters/criteria could be considered by authorities as part of the MCA approach to inform future investment plans for integrated investments for priority buildings.

**Figure 29.** Four-step approach for portfolio assessment of CP infrastructure

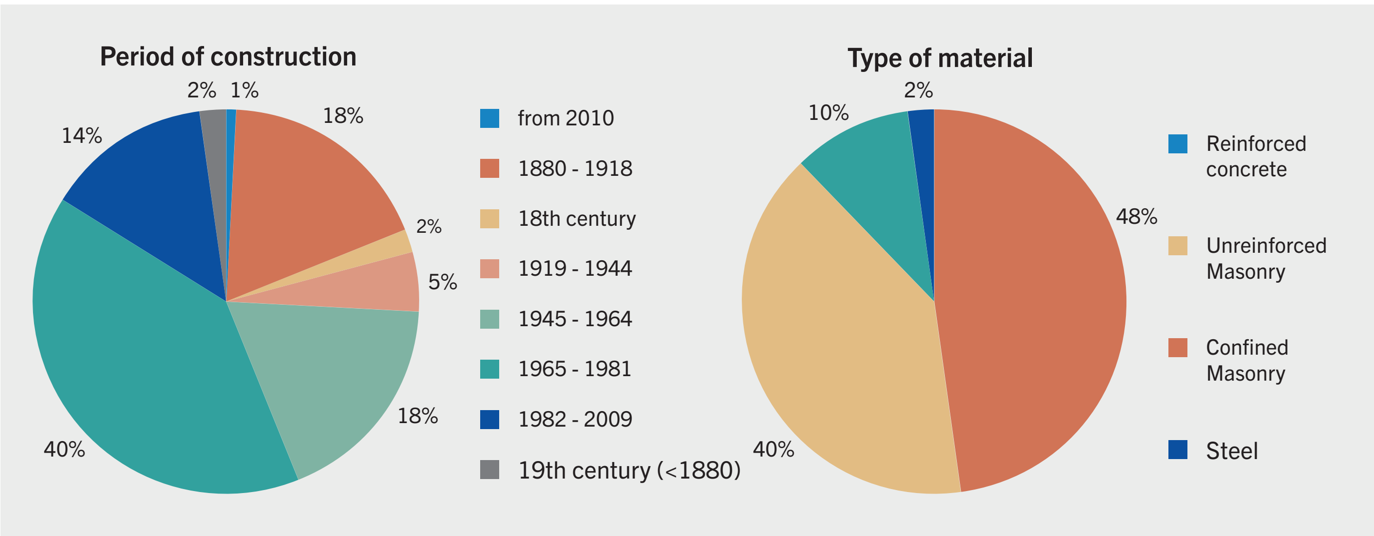



*Source:* World Bank.

## SUMMARY OF FINDINGS

**Step 1: Portfolio-based analysis of CP infrastructure.** According to the collected data so far, reinforced concrete (48 percent) is the most used type of material, followed by unreinforced masonry (40 percent), confined masonry (10 percent), and steel (2 percent). Apart from the fact that these buildings are generally old (note, three percent built in the 18th and 19th centuries, 18 percent built between 1880 and 1918, and another 18 percent built between 1945 and 1964) and not designed for earthquake loads, the problem also lies in their poor maintenance and subsequent alterations, additions, and changes in occupancy. Figure 28 shows results related to the type of material and period of construction and others.

**Figure 30.** Analysis based on data collected through surveys/supplemental research



The AALs amount to €171,250/300,409[120] (considering value of statistical life[121]). The AAL ratio for the country's CP/emergency response sector is 0.08 percent, but in some buildings this value goes up to 0.4 percent. Approximately two-thirds of the AAL is generated in the city of Zagreb. Economic loss ratios in the case of earthquakes with return periods of 95 years and 475 years are between 1 percent and 9.5 percent, respectively, considering only damage to buildings.

**Step 2: Additional analysis related to energy efficiency.** From the data, it is visible that most of the buildings have poor performance in terms of energy efficiency, not in line with the current EU and national policies. The average annual consumption in the last five years (2018–2022) of the 35 buildings in the CP portfolio is 125.6 kWh/m$^2$. The assumption used for calculations was that all buildings built before 1981 (more than 80 percent of the analyzed buildings) need to go through a comprehensive energy renovation while the rest of the buildings need softer measures. The aim is to reach the consumption of 50 kWh/m$^2$ or lower (which would be A+ grade for other nonresidential buildings) and increase safety. Comprehensive energy renovation, as per Long-Term Buildings Renovation Strategy for Croatia and in line with European norms, implies several energy renovation measures. It is mandatory to include at least one measure on the building envelope as well as measures related to technical systems. It requires achieving savings of at least 50 percent of the annual required heat energy for heating and at least 50 percent of primary energy on an annual basis. In addition to energy renovation measures, the comprehensive renovation includes measures to increase safety in the event of earthquakes or fires and improve indoor climatic conditions.

**Step 3: Quantification of benefits and costs.** The process followed steps in line with the TDR approach. Related to costs, unit replacement costs were established for the different types of CP buildings. Costs (and potential damage) to equipment and the content of these buildings were not considered. Direct losses for every building in the CP/emergency response portfolio in its original (un-retrofitted) state and aggregate the values for the CP/emergency response subsectors were calculated. The cost of retrofitting and replacing CP/emergency response buildings was calculated based on market prices and expert judgment. In total, for the 64 buildings analyzed, the total expected replacement cost was €209,304,150 while the seismic retrofit cost was €63,475,330,000. The benefit of average annual avoided losses was calculated as €300,409. Related to indirect losses, replacement cost of about US$136.1 billion per the GEM model. Considering benefits, the number of occupants for each operational area of these assets was calculated. The total number of avoided fatalities in collapsed buildings was calculated, considering the statistical value of life of €6,000,000,[122] with average annual benefits from the lives saved of €17,936,584. Related to energy efficiency, energy consumption, related costs, and $CO_2$ emissions of the CP/emergency response buildings in their current (un-retrofitted) state as well as cost of energy renovation solutions were calculated. Benefits (due to reduced costs of electricity and $CO_2$ emissions) consider avoided costs of electricity (€920,061) and avoided costs of $CO_2$ emissions for 20 years (€722,466) and 50 years (€1,519,058).

Based on the above, the analysis determined the NPV, BCR, estimated RoR, and payback period for the proposed retrofitting solutions for two planning horizons (20 and 50 years). A summary of the results is presented in Table 6. The results show positive BCRs for seismic retrofit and energy efficiency, especially considering 50-year life cycle of buildings.

120 The first value relates to the vulnerability of buildings, while the second value includes the potential fatalities in the CP sector buildings.

121 The value of statistical life (VSL) is a concept often used in BCA to estimate the monetary value of preventing a single human life lost. It represents the amount of money that society is willing to spend to reduce the risk of a fatality in various activities or situations. In the studies presented, a VSL of €6 million is used based on a study by Viscusi and Masterson. The VSL is the marginal rate of substitution between income (wealth) and mortality risk, that is, how much individuals are willing to pay on average to reduce the risk of death. It does not indicate the value of an actual life but the value of marginal changes in the likelihood of death.

122 World Bank and European Commission 2021b.

**Table 6.** CP portfolio review - BCA results

| SEISMIC RETROFIT + ENERGY RENOVATION | PLANNING PERIOD (YEARS) | | SEISMIC RETROFIT/ REPLACEMENT OF THE MOST VULNERABLE BUILDINGS + ENERGY RENOVATION | PLANNING PERIOD (YEARS) | |
|---|---|---|---|---|---|
| | 20 | 50 | | 20 | 50 |
| **Discount rate** | 0.05 | 0.05 | **Discount rate** | 0.05 | 0.05 |
| **BCR** | 2.45 | 4.07 | **BCR** | 2.05 | 3.39 |
| **NPV (EUR)** | 115,227,424 | 242,809,696 | **NPV (EUR)** | 99,530,135 | 227,112,406 |
| **ERR (%)** | 21.2 | 22.9 | **ERR (%)** | 17.1 | 19.1 |
| **Payback period** | 9 | 9 | **Payback period** | 10 | 10 |

*Source:* World Bank.

Step 4: **Recommendations for a prioritization framework, including various criteria.** In addition to the evidence gathered and provided through the above analysis and costing, the following criteria could be considered as part of a full-fledged MCA that may be highly relevant for the Croatian context:

- **Disaster and climate risk**
  - Disaster vulnerability (existing analysis)
  - Consideration of other hazards, including floods, wildfire, and extreme heat (overlying of additional risk information and spatial analysis)
  - Consideration of future climate conditions and expected increases of annual losses and so on

- **Service-related criteria**
  - Importance of specific buildings within the whole system/within county or nationwide
  - Requirements related to the time of response or other service/performance-level criteria that fire stations or operation centers are required to meet
  - Area (catchment) and number of people (beneficiaries) covered by these buildings
  - Number of calls per year
  - Social aspects—population trends, accessibility in relation to expected impact, ratio of potentially vulnerable population

- **Functionality related**
  - Information on other standards or norms/ regulations or targets (that is, energy efficiency targets, sanitation norms, fire codes, and so on)
  - Buildings functionality versus compatibility of equipment

- **Strategic related**
  - Considerations of past/planned energy efficiency/other upgrading
  - Inclusion/prioritization of areas/buildings in existing investment plans
  - Availability of funds (ongoing/planned calls of proposals and so on).

## LESSONS LEARNED AND RECOMMENDATIONS

**This kind of analysis provides rapid yet robust overview of the state of the portfolio of emergency response-related assets while also highlighting options for interventions and broader recommendations to consider as part of a prioritized approach to investments.** The study comprehensively assessed seismic, economic, and energy efficiency aspects, offering insights into the cost-effectiveness of retrofitting CP buildings over different time frames and discount rates.

**The seismic risk assessment shows that a large number of emergency response buildings were built before modern seismic regulations and are highly vulnerable to seismic risk, some of them in the regions of high-seismic hazard.** In the case of a major earthquake, there may be significant impact on the ability of critical infrastructure to respond to such an event as it cannot be expected that they stay operational. The potential indirect impacts could be substantial and not all can be quantified easily. The results show that majority of critical infrastructure need urgent measures to make them seismically (and disaster) safe and more efficient in terms of the energy consumption. The analysis also shows that investment will bring economic and socio-environmental benefits and these benefits will outweigh costs in the longer term. An intervention strategy aimed at mitigating the risk could be developed as a next step, considering the following:

- Identify potential funding *opportunities for pilot project(s),* for example, through Cohesion Policy Funds.
- Focus on the preparation of *feasibility-level studies.*
- Identify *representative retrofits* for various building typologies, including energy efficiency improvements—that is integrated/smart solution. This can help ensure cost-effective, scalable interventions.
- *All key characteristics of critical infrastructure buildings* should be considered strategically and continuously.
- Consider developing a *prioritization framework.*
- *Data collection*. While analysis is possible even with limited data, there should be an effort to continue in parallel improvement of data. This can continue improving robustness of data and help operationalize the results. More specific data on buildings are necessary to perform climate-proofing as some aspects depend on geographical location and specific position of the building.

**Based on this analysis, several lessons learned/ recommendations can be made for Croatia as well as other countries facing similar challenges:**

- *Importance of spotlighting CP buildings*. Identifying buildings that are potentially vulnerable and unusable after major disaster events provides important information for future strategic actions. It is critical to reduce risks for these buildings or seek lower-risk replacement buildings that would function safely after a major event. CP should be an example of action as it is a key element of the overarching DRM system. Prioritized risk reduction in this sector could also help raise awareness of DRM among the society and across other sectors at risk such as education, health, and transport.
- *Importance of prioritization.* Prioritization of intervention equals more people saved when the next big earthquake will hit and more efficiency in the retrofitting investments. This kind of analysis provides the underlying data to prioritize effectively.
- *Importance of using the data available while also investing in robust data collection process.* The more accurate and detailed the data collected, the more accurate investment estimates and the more efficient investments. However, requiring too much/too detailed data risks hindering the process and introduces more error. Data collection can take time, especially in countries where building records are poor/non-consistent. There is a need to employ data collection methods that are simple yet able to provide robust results. This is possible and can provide sufficient level of detail for robust analysis, while further analysis can be undertaken in parallel.

- *Linking seismic risk information with other hazards in a meaningful way.* In the context of data constraints, spatial exposure analysis can provide supplemental information that can be considered, if not in a quantitative manner, as part of the MCA prioritization framework. As relevant, this study demonstrated the use of exposure analytics.

- *Importance of co-benefits.* Investing in seismic risk reduction offers an opportunity for other types of upgrades. For example, in the case of Romania, upgraded fire stations are equipped with male and female toilets and are nearly zero-energy buildings (reducing operation costs and emissions), and they will benefit from functionality and comfort upgrades to improve the performance and capacity of the services, with even wider benefits to the local communities.

- *Linking DRM and CCA in a meaningful way.* Climate-proofing integrates both mitigation and adaptation efforts. EC guidelines provide a practical way to integrate climate-proofing into investment planning. Even with limited information, there are opportunities to identify no- or low-regret solutions and combine DRM and CCA agenda in an impactful and practical manner.

- *Role of decision-makers.* While a major part of the analytics can be driven by technical experts, ideally, stakeholders are involved in the process from the very beginning to ensure ownership and matching of needs. Especially in view of the prioritization frameworks, consultations and stakeholder input on decision criteria and their weighting are essential.

## Portugal - Vulnerability and Benefit-Cost Analysis for National Wildfire Risk Reduction Program

**The case study on Portugal used a vulnerability analysis and BCA to evaluate the benefits of wildfire risk reduction under the voluntary SVSP program and in view of near-future wildfire scenarios.** The analysis assessed impacts in terms of life safety, injury avoidance, and overall preparedness of villages. The proposed prioritization scheme considers how districts/regions with villages may experience reduced losses given current and increased adoption rates of the program (that is, increased defensible space, preparedness measures, and so on) with consideration of demographic and economic impacts. The analysis shows that the SVSP program is an important and useful initiative to promote wildfire risk awareness among the population and visitors of highly exposed villages in rural Portugal. The findings can guide future decisions about resource allocation and wildfire risk reduction, increasing the impact and thus resilience of communities. **These analytical tools can be highly relevant to UCPM members facing wildfire risks/ having in place similar risk reduction/prevention programs or planned to roll out such programs.**

### BACKGROUND

**Portugal is prone to several natural hazards and faces significant risk of wildfires and heatwaves and, to a lesser extent, drought, flooding, earthquakes, tsunamis and coastal erosion.** The climate regime, with a temporal coincidence of warm and dry months, makes the country susceptible to drought conditions and rapid fire spread, especially during the summer. Wildfires can have devastating consequences in Portugal, including damage to forests, loss of property, and threats to human lives. The frequency and severity of wildfires have been exacerbated by factors like deforestation, changes in land use, and climate change. The EU-wide exposure analysis described in Chapter 1 shows that 80 percent of Portugal's emergency response-related assets are exposed to high or very high wildfire hazard with a subset of those in areas exposed to high levels of earthquake or landslide too.

**Following extreme wildfire events in 2017 that burned about 500,000 ha of land and killed more than 100 people, the Portuguese government created the SVSP program.** The objective was to enhance community preparedness and response to wildfires and foster a collaborative approach between government authorities, emergency services, and local communities.[123] The program's main objectives are to improve wildfire prevention through fuel management, increase the safety of people living in at-risk areas, and strengthen the capacity to respond effectively in case of a wildfire. Participation in the program is voluntary and initiated by local authorities (i.e., municipalities and civil parishes); there is no formal prioritization scheme put in place by SVSP program administrators.

**The 'Safe Village' sub-part of the program established structural measures for the protection of people and property, as well as buildings situated at the urban-forest interface, identifying critical points and places of refuge.** Under the SVSP program, villages pursue at least one of the measures in the following areas: (a) preventing risky behavior through awareness campaigns to reduce the number of ignitions caused by anthropogenic actions; (b) raising awareness about wildfire risk levels and self-protection practices (through the nomination of Local Safety Officers or fire drills for example); (c) developing and promoting evacuation plans; and (d) creating shelters and places of refuge during the passage of the fire.

**On the other hand, the 'Safe People' sub-program promotes awareness-raising campaigns against risky behavior and encourages self-protection measures and designs evacuation drills, in liaison with local authorities.** As of April 2024, about 2,250 villages across Portugal have joined the program, nearly 1,900 local safety officers were appointed, about 2,900 shelters and places of refuge were put in place, and over 900 local evacuation plans were established. Until today, over 32,500 people participated in over 960 awareness campaigns, and more than 12,800 people took part in nearly 500 drills and exercises.

**A recent assessment**[124] **for the parish of Alvares, which comprises 36 settlements and slightly over 800 citizens,** acknowledged that wildfire risk management cannot be disconnected from subnational development and land use planning policies in low-density regions, and especially in view of climate change, it was recommended to invest in various self-defense measures and institutional capacity building. According to the authors, demographic changes, aging population, and reduction of farming activities and subsequent land abandonment make it imperative to find new economic models to simultaneously create value for local citizens and manage the wildfire risk effectively.

**Another study in 2022 analyzed the implementation of the SVSP program in the Algarve region in the south of Portugal.** [125] Through a wildfire risk assessment, the authors determined the percentage of high and very high hazard levels in the critical areas surrounding municipalities (that is, fuel management area within 100 m around a settlement) and the share of 'safe villages' within each municipality. The study found out that in Algarve the high and very high hazard levels cover 6.6 percent of the 100 m buffers around the built-up areas of the region and the municipality of Monchique had by far the highest percentage (62 percent). This articulation enabled a better definition of priorities, namely in the location of safe villages, and a better implementation of fuel management around a settlement. The study noted that more settlements should become 'safe villages' and the program could be aligned with other initiatives associated to fuel management and landscape transformation to increase the self-protection capacity of the population and mitigate the consequences of large wildfires.

123 For more details, see Government of Portugal. Safe Village, Safe People [*Aldeia Segura Pessoas Seguras*]. Link.

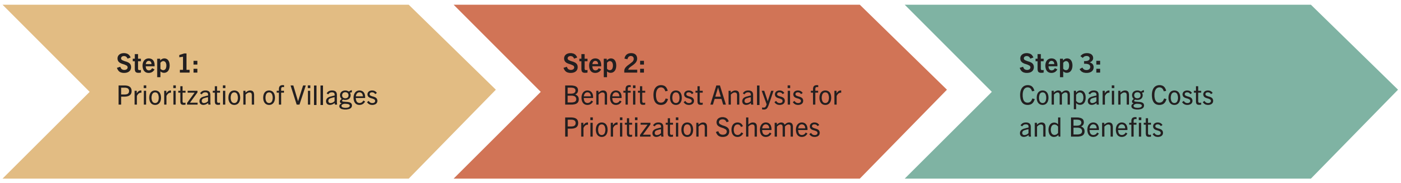
124 Oliveira, Sandra, Ana Gonçalves, Akli Benali, Ana Sá, José Luís Zêzere, and José Miguel Pereira. 2020. "Assessing Risk and Prioritizing Safety Interventions in Human Settlements Affected by Large Wildfires" Forests 11 (8): 859. Link.

125 Gonçalves, A., S. Oliveira, and J. Zêzere. 2022. *Implementation of "Safe Villages" Settlements with Surrounding Areas of High Hazard to Wildfire: Outlook from the Algarve Region*. Link.

## STEPS IN THE ANALYTICAL PROCESS

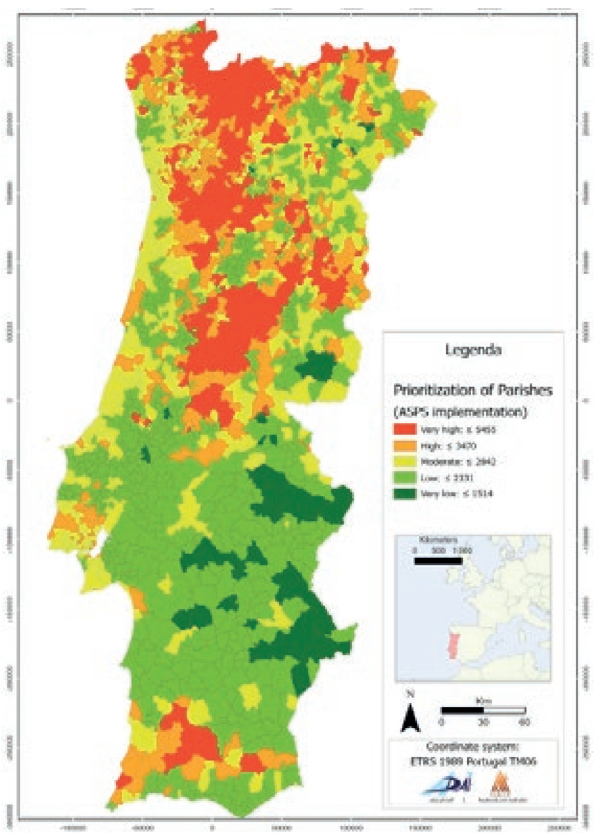
**The analysis employed a data-driven approach that combined expert knowledge and geographic data analysis to propose a prioritization scheme for villages for SVSP program support based on various factors influencing wildfire risk.** It also conducted a comprehensive BCA to assess the program's economic viability under different scenarios. This methodology served as a robust framework for making informed decisions about resource allocation and wildfire risk reduction in Portuguese civil parishes. The analysis followed three main analytical steps:

**Figure 31.** Three-step approach for the BCA of national wildfire risk reduction program and in view of future scenarios




**Step 1: Prioritization of Villages.** This step involved multiple criteria to prioritize villages. It employed GISs and various data sets, including information from government agencies, census data, social vulnerability data, and climate projections. Key parameters for village selection include the housing index, WUI, wildfire risk, population index, social vulnerability, and future climate projections. These parameters were weighted based on their influence. A series of ArcGIS models are used to combine data sets and determine prioritization, resulting in a clear order of priority for SVSP program implementation. The final classification consists of the combination of all these individual results, as depicted in Figure 32.

**Figure 32.** Result of the application of the prioritization model applied to Portugal's parishes




*Source:* World Bank.

The following is a prioritization of moderate- to high-risk parishes, which contain moderate- to high-risk villages, by NUTS3 classification, and ordered in terms of sequential ranking of the number of parishes within each subregion that has very high-risk to low-risk parishes. In other words, subregions are ordered by the risk intensity of their parishes. Due to data limitations of determining the exact number of villages within each parish, analysis has been conducted at the civil parish level and the assumption is that if a parish is considered high risk, all villages within that parish will also be high risk. Those parishes with large city centers generally do not have very high prioritization levels (that is, high risk levels), which speaks to the correlation of rurality and high wildfire risk (see description of factors determining risk class in the previous section). Also, 23 subregions/NUTS3 presented represent the mainland Portugal subregions of Portugal and do not include the island regions.

**Table 7.** Prioritization by subregion/NUTS3

| NUTS3/SUBREGION NAME | RISK CATEGORY | | | | |
|---|---|---|---|---|---|
| | VERY HIGH | HIGH | MODERATE | LOW | VERY LOW |
| | NO. OF PARISHES PRIORITY 1 | NO. OF PARISHES PRIORITY 2 | NO. OF PARISHES PRIORITY 3 | NO. OF PARISHES PRIORITY 4 | NO. OF PARISHES PRIORITY 5 |
| **Beiras e Serra da Estrela** | 91 | 76 | 54 | 45 | 0 |
| **Tâmega e Sousa** | 67 | 90 | 20 | 0 | 0 |
| **Alto Minho** | 67 | 83 | 42 | 16 | 0 |
| **Alto Tâmega** | 59 | 33 | 14 | 12 | 0 |
| **Ave** | 56 | 51 | 49 | 12 | 0 |
| **Região de Coimbra** | 56 | 26 | 34 | 52 | 0 |
| **Viseu Dão Lafões** | 45 | 43 | 20 | 48 | 0 |
| **Douro** | 43 | 37 | 72 | 63 | 2 |
| **Área Metropolitana do Porto** | 34 | 30 | 90 | 19 | 0 |
| **Cávado** | 26 | 29 | 79 | 36 | 0 |
| **Terras de Trás-os-Montes** | 18 | 48 | 55 | 68 | 6 |
| **Médio Tejo** | 16 | 24 | 11 | 41 | 1 |
| **Região de Leiria** | 11 | 12 | 27 | 17 | 0 |
| **Beira Baixa** | 7 | 11 | 19 | 18 | 4 |
| **Algarve** | 4 | 13 | 10 | 40 | 0 |
| **Baixo Alentejo** | 3 | 2 | 3 | 42 | 12 |
| **Alentejo Litoral** | 2 | 4 | 5 | 19 | 1 |
| **Região de Aveiro** | 1 | 16 | 47 | 10 | 0 |
| **Alto Alentejo** | 1 | 3 | 13 | 31 | 21 |
| **Área Metropolitana de Lisboa** | 0 | 33 | 59 | 26 | 0 |
| **Oeste** | 0 | 7 | 35 | 47 | 0 |
| **Lezíria do Tejo** | 0 | 1 | 4 | 61 | 2 |
| **Alentejo Central** | 0 | 0 | 3 | 47 | 19 |

*Source:* World Bank.

**This comprehensive approach identified those civil parishes most in need of SVSP program support by considering various factors that influence the risk and impact of wildfires.** The final results are classified into categories such as 'very high', 'high', and 'moderate' to provide a clear order of priority for the implementation of the program. Overall, this prioritization methodology is data driven and used a combination of expert knowledge and geographic data analysis to make informed decisions about where to allocate resources for wildfire risk reduction and support.

**Step 2: BCA for different prioritization schemes.** This step assessed the value of investing in scaling the SVSP program by conducting a BCA. This analysis utilized the prioritization scheme developed in Step 1 and distributed the high-risk villages in six different arrangements within the analysis period between 2024 and 2050. The program costs, including safety officers, shelter or refuge places, evacuation plans, and drills, were considered and unit costs were adjusted based on the village size. Additionally, municipal-level costs are determined for elements like safety officers and deputies, fire shelter, and prevention plans. Benefits were categorized into impacts on individuals, infrastructure, eco-social aspects, economic aspects, and operational aspects. Benefits are presented as costs avoided due to SVSP implementation. These costs avoided are then scaled based on risk factors, considering high- and low-risk villages. The analysis considered trends in SVSP implementation and scenarios that increased the number of participating villages annually.

**The BCA considers six unique scenarios in which the number of participating villages is increased annually within the timeline between 2024 and 2050.** Given the prioritization conducted in Step 1, the BCA pursues three scenarios and calculates BCR for each of them.

Plans A1 and A2 share a similar village distribution among risk classes but exhibit different cost and benefit trajectories. **There are four 'Plan B' scenarios which all consider a complete restart of the program and define participatory requirements and evolution according to the prioritization.**

The plans and their 2024 and 2050 participation targets are summarized in Table 8. There is a higher number of participating villages in the moderate- to high-risk categories and lower number of participating villages in the low- to very-low-risk categories. The total number of expected participating villages is the same in all six plans for sake of comparison Table 9 summarizes all plans analyzed in this study with a brief description and including the start- and end-year participating villages.

**Table 8.** Village risk level and participating target for 2050 for scenarios B1–4

| VILLAGE RISK | 2050 PARTICIPATION TARGETS (VILLAGES) | | | |
|---|---|---|---|---|
| | B1: REASONABLE DISTRIBUTION | B2: PRIORITIZING VERY HIGH AND HIGH RISK | B3: CURRENT STATE DISTRIBUTION | B4: EQUAL DISTRIBUTION |
| **Very high risk** | 2,000 | 2,500 | 1,222 | 750 |
| **High risk** | 1,000 | 1,250 | 1,078 | 750 |
| **Moderate risk** | 500 | 0 | 527 | 750 |
| **Low risk** | 250 | 0 | 908 | 750 |
| **Very low risk** | 0 | 0 | 15 | 750 |
| **TOTAL participating villages by 2050** | 3,750 | 3,750 | 3,750 | 3,750 |

*Source:* World Bank.

**Table 9.** Summary of all scenarios ('Plans')

| PLAN | DESCRIPTION | TOTAL PARTICIPATING VILLAGES | |
|---|---|---|---|
| | | 2024 | 2050 |
| **A1** | Current state program with additional critical Measures: Additional programmatic measures per participating village; distribution of villages in risk categories based on participation to date | 2,313 | 3,750 |
| **A2** | Current state program with National Civil Protection Authority (ANEPC) measures: No additional programmatic measures per participating village; distribution of villages in risk categories based on participation to date | 2,313 | 3,750 |
| **B1** | Program starting from scratch with reasonable distribution among village risk categories | 225 | 3,750 |
| **B2** | Program starting from scratch with prioritization of distribution on very-high-risk and high-risk villages | 225 | 3,750 |
| **B3** | Program starting from scratch with current state distribution proportions, similar to A1 and A2 distributions | 225 | 3,750 |
| **B4** | Program starting from scratch with equal distribution among risk classes | 225 | 3,750 |

*Source:* World Bank.

**Step 3: Comparing benefits and costs.** This step involved comparing the benefits and costs of the SVSP program under the different scenarios outlined in Step 2. BCRs and net benefits were calculated for each scenario (Plan A1, A2, and B1–4) based on the number of participating villages and their prioritization. The scenarios have different levels of funding and requirements, allowing for a comprehensive evaluation of the program's cost-effectiveness.

The total benefits and costs for these three cases were calculated by multiplying the annual number of participating villages within each risk category by the unit implementation cost and the unit benefit (losses avoided cost). This approach yielded annual total benefits and costs, which were then discounted to 2023 using a five percent discount rate.

Computing total discounted costs and total discounted benefits provides a BCR for each case. In addition, a net benefit calculation is provided, which subtracts total discounted costs over the analysis period from the total invested benefits. This provides a net benefit in present (2023 euro) terms to be able to understand overall value of the six investment schemes. The BCR and the net benefits are provided in Table 12.

**Table 10.** BCRs and net benefits per scenario (5 percent discount rate)

| PLAN | DESCRIPTION | BCR | NET BENEFIT (€, MILLIONS) |
|---|---|---|---|
| **A1** | Current state program with additional critical measures: Additional programmatic measures per participating village; distribution of villages in risk categories based on participation to date | 1.51 | 330.5 |
| **A2** | Current state program with ANEPC measures: No additional programmatic measures per participating village; distribution of villages in risk categories based on participation to date | 1.64 | 233.3 |
| **B1** | Program starting from scratch with reasonable distribution among village risk categories | 1.88 | 330.0 |
| **B2** | **Program starting from scratch with prioritization of distribution on very high-risk and high-risk villages** | **2.13** | **432.1** |
| **B3** | Program starting from scratch with current state distribution proportions, similar to A1 and A2 distributions | 1.50 | 184.9 |
| **B4** | Program starting from scratch with equal distribution among risk classes | 1.36 | 107.9 |

*Source*: World Bank.

## SUMMARY OF FINDINGS

Plan A1 and Plan A2 consider the current state of the program and begins with the village distribution per risk category as it is currently deployed in Portugal. A1 includes additional critical program measures requirements (safety officers, prevention plans, and emergency plans) and provides a BCR of 1.51 and a net benefit during the analysis period (2024–2050) of €330.5 million (in 2023 euro). Plan A2 (with current ANEPC measures) presents a BCR of 1.62 and a net benefit during the analysis period of €233.3 million (in 2023 euro). **Plan A2 has a slightly higher BCR due to lower costs associated with the program (without additional programmatic elements) compared to Plan A1.**

Plan Bs consider the SVSP program starting from scratch in 2024. Plan B1 which considers a reasonable distribution reflecting the historical patterns of adoption and informed by analysts experience with the program projected to 2050 has a BCR of 1.88, with a net benefit of €330.0 million (in 2023 euro). Plan B2 which considers an aggressive distribution of high-risk and very-high-risk villages shows a BCR of 2.13 and a net benefit of €432.1 million (in 2023 euro). Plan B3 reflects the current state distribution proportions similar to A1 and A2 but starts the program from scratch and obtains a BCR of 1.50 with net benefits of €184.9 million (in 2023 euro). Finally, Plan B4 is the program starting from scratch in 2024 with equal distribution by risk class and presents a BCR of 1.36 with a net benefit of €107.9 million (in 2023 euros). **Overall, Plan B2 is an ideal evolution of the SVSP program provided as a comparison to current state implementation of SVSP, with more or less investment in programmatic elements** (Plan A1 and A2, respectively). It is important to note that all scenarios have cumulative BCRs higher than 1, indicating that investments will produce more benefits than costs over time.

## LESSONS LEARNED AND RECOMMENDATIONS

**The SVSP program is an important and useful initiative to promote wildfire risk awareness among the population and visitors of highly exposed villages in rural Portugal.** This case study demonstrated that prioritization, adaptability, and thorough analysis are crucial elements in addressing wildfire risk and highlighted the benefits of investing in high-risk areas, promoting collaboration, and considering demographic and economic shifts in risk reduction strategies.

From this analysis, the following key lessons can be drawn:

- *Importance of prioritization.* The study highlighted the significance of prioritizing investments for wildfire risk reduction programs. Given limited resources and the vast adaptation needs across Portugal, prioritization helps allocate resources more effectively to areas that need it the most, thereby maximizing a program's impact.

- *Emphasis on high-risk areas.* The research showed that investing in high-risk areas provides higher benefits over costs over time. Prioritizing villages in areas with a greater risk of wildfires leads to greater benefits, as these areas are more susceptible to losses, in terms of both lives and property. This suggests that targeted investment in high-risk regions should be a focus of wildfire risk reduction efforts.

- *Need for adaptability.* The study underscored the importance of adapting programs to evolving needs and challenges, especially in view of climate change. The SVSP program could benefit from additional resources, revised criteria for village selection, enhanced personnel training, and community engagement. Being flexible and responsive to changing circumstances is crucial for long-term program success.

- *Cross-sector collaboration*. The SVSP program's approach, which fosters collaboration between government authorities, emergency services, and local communities, points toward the importance of cross-sector cooperation in addressing wildfire risks which can lead to more effective and sustainable solutions.

**Policy recommendations to enhance Portugal's capacity to manage and reduce wildfire risks and gleaned from this study include the following**:

- *Allocate resources based on risk assessment.* Investment in emergency preparedness as well as awareness raising in the most vulnerable regions of Portugal is essential for wildfire risk reduction and life safety. This requires sustained funding for tools and training based on the severity of the risk faced by villages, communities, and municipalities.

- *Prioritize high-risk villages for immediate action.* Evaluating fire risk in multiple dimensions, including the consideration of social vulnerability, is crucial for understanding overall risk and prioritizing investment needed for risk reduction.

- *Update program criteria and guidelines.* Regularly review and update the criteria for village selection to ensure they align with changing wildfire risk factors and consider expanding eligibility criteria for villages in regions with increasing risk due to factors such as climate change.

- *Account for demographic and economic factors.* Addressing rural exodus and seasonal international and domestic tourism as part of overall wildfire emergency management and risk reduction is imperative to have seasonal readiness and awareness of wildfire risk management.

- *Promote investment in training.* Allocating resources for the training and capacity building of safety officers and other personnel involved in wildfire risk reduction programs ensures that those responsible for managing risks are adequately prepared and equipped. Because it sometimes proved difficult to find volunteers to take on the role and responsibility as local safety officers, some form of sustained financial compensation should be considered to minimize the possibility of the program being impeded due to lack of volunteer capacity.

## Romania - Using Network Criticality Approach and MCA for a Resilient Transport Network

**This case study demonstrates the use of national criticality and vulnerability analysis to better understand which transport segments are most vulnerable to flood events and the magnitude of transport disruption caused by those events.** The objective of the analysis is to support evidence-based decision-making, inform policy planning and subsequent more detailed analysis, and prioritize investments. These can be both investments to improve the resilience of the existing network (for example, increasing drainage capacity of existing roads) and investments to increase the redundancy of the whole network (for example, adding new road segments or railway tracks). Using network criticality analysis, this case study helped identify the relative importance of individual road segments and the most vulnerable users of infrastructure services. By identifying bottlenecks and vulnerability hotspots, this kind of analysis helps prioritize investments in disaster and climate resilience. ***These analytical tools can be highly relevant to UCPM members with critical assets at flood risk/at risk from other or multiple natural hazards.***

### BACKGROUND

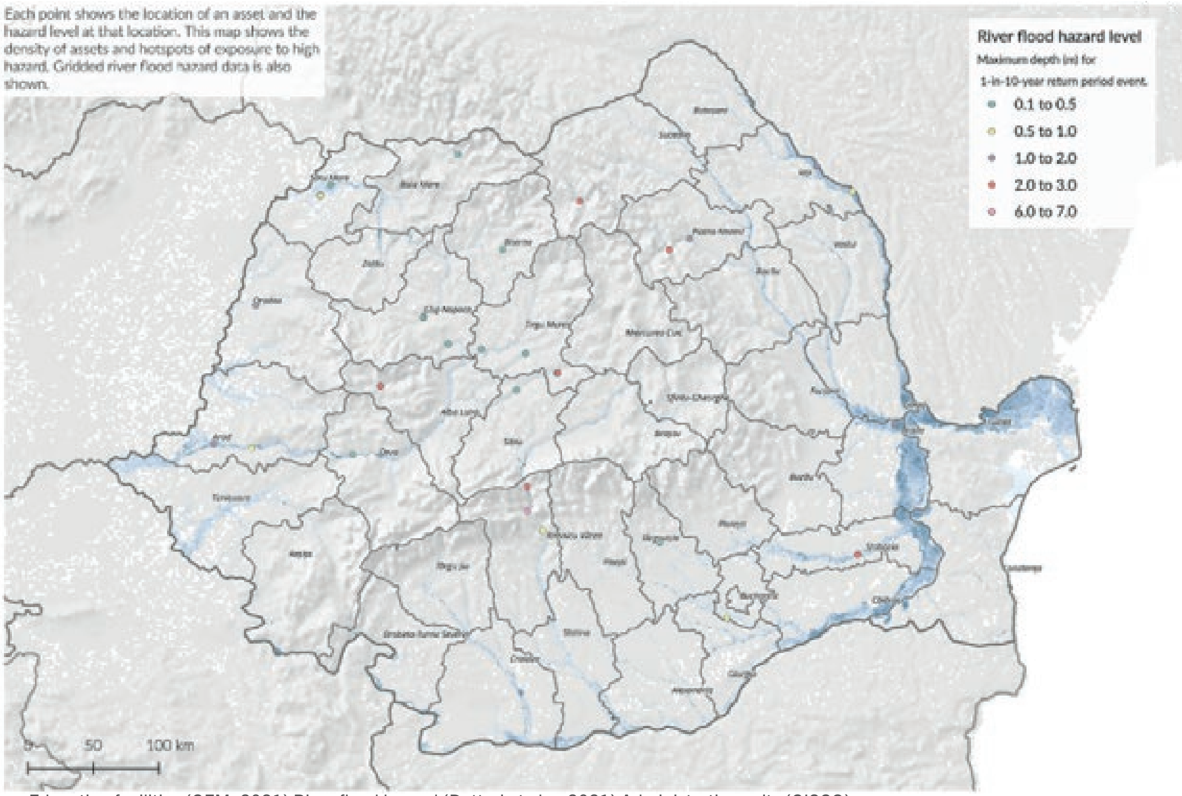
**Romania's population and economy are exposed to a series of risks due to a range of hazards, including natural, biological, and technological.** Between 1900 and 2023, international disaster database EM-DAT reported 103 natural hazards in Romania, affecting 2.058 million people and causing 7,396 deaths and total estimated damage of US$19.42 billion.[126] Floods have caused up to 20 times higher losses than seismic losses, with an estimated 300,000 people and US$2 billion of Romania's GDP affected by flooding on average. In accordance with the EU Floods Directive, Romania has prepared Flood Risk Management Plans (FRMPs) for its twelve units of management (UoMs) to, among others, adapt infrastructure to the flood risk and to climate change[127] by revising technical norms, improving infrastructure inventory, and focusing on at risk assets, among others.[128] Romania's road and rail networks—like other critical infrastructure—are significantly exposed to this range of hazards. For example, it is estimated that six percent of the national railway and 700 km of major highways, national, and European roads as well as 1,300 km and 1,000 km of county and local roads, respectively, are at risk of floods.[129]

**The rapid exposure analysis did not reveal high exposure of CP assets to high flood hazard in Romania.** Among the countries' CP assets, the education sector and police stations are most exposed with each around a dozen of facilities exposed to 1 meter or more of water depth in case of a 1-in-10-year flood event (see Figure 33), compared to only a few health facilities and fire stations. Generally, where flood protection is in place, the standard of protection would exceed the R10 event, so such a frequent event would not be expected to inundate those assets; however, these maps are indicative of the assets which could be most severely affected in more extreme events that overcome available flood protection.

126 CRED and UCLouvain 2024.
127 The plans were based on the identification of 526 areas of potential significant flood risks, leading to the creation of new hazard and risk maps and programs of measures (PoMs) that prioritize sustainable interventions and integrate nonstructural measures, green infrastructure, and NBSs.
128 World Bank. 2023b. "Report on Advice Provided to MEWF in the Preparation of Twelve (12) Final Draft Flood Risk Management Plans." Output 7 of the Reimbursable Advisory Services Agreement (RAS) on Technical Support for the Preparation of Flood Risk Management Plans for Romania.
129 *See* Government of Romania. 2016. *Country Report 5.1 Conditionality Romania*. RO-RISK. Link. p. 26.

**Figure 33.** Distribution of education facilities and river flood hazard in Romania

Distribution of emergency response related assets and river flood hazard Education facilities, Romania




*Data Sources:* Education facilities (GEM, 2021) River flood hazard (Dottori et al;... 2021) Administrative units (GISCO)

*Source:* World Bank, as part of EU-wide exposure analysis.

## STEPS IN THE ANALYTICAL PROCESS

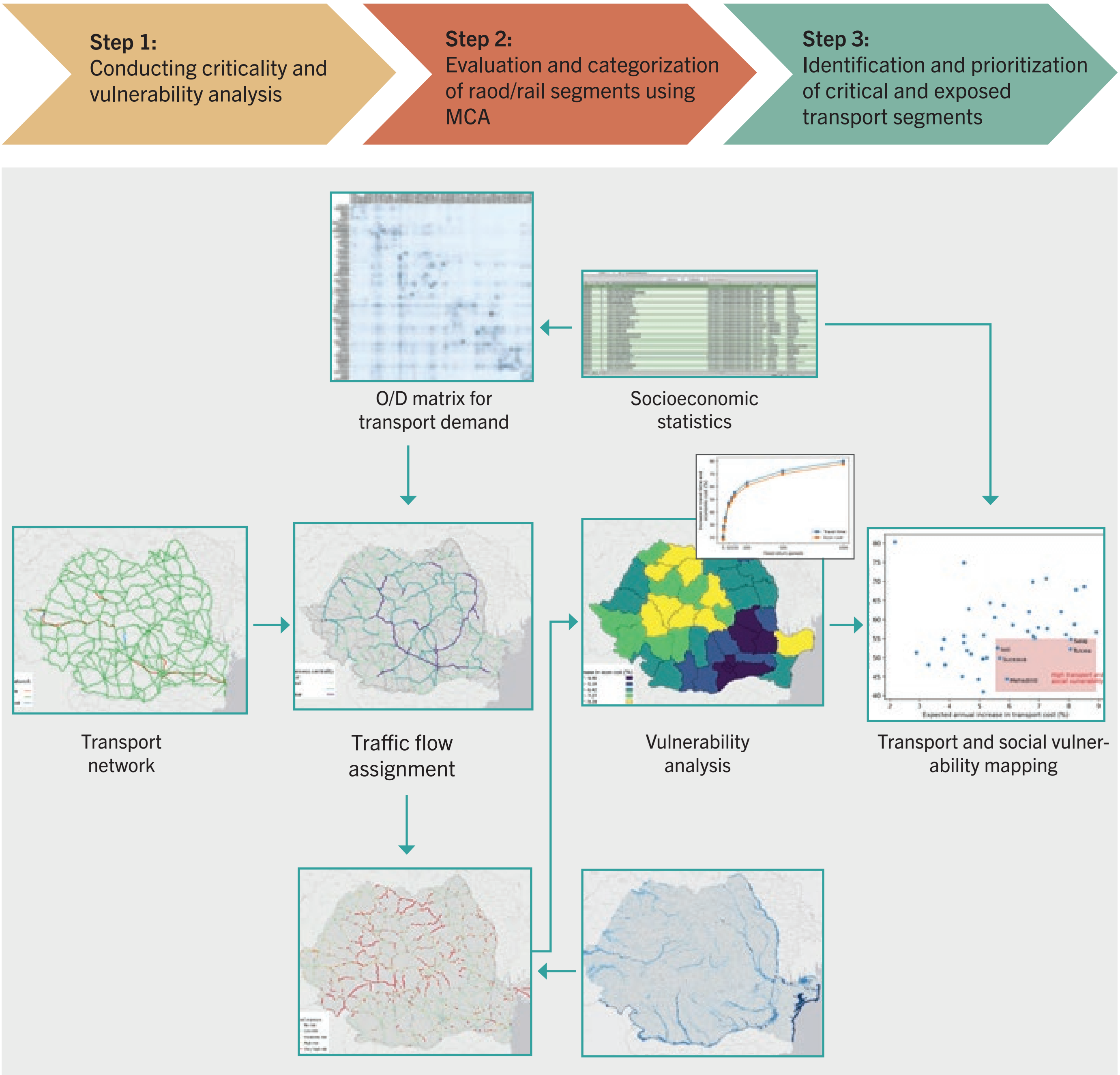
**The case study on Romania followed three main analytical steps:**

**Step 1: Conducting criticality and vulnerability analyses.** Romania's road and rail networks were analyzed based on criticality and vulnerability aspects of its infrastructure to determine which transport segments are the most critical for maintaining overall functionality and how much transport users would suffer from a reduction in functionality in case of a shock or disaster.

**Step 2: Evaluation and categorization of road/rail segments using MCA.** By incorporating socio-economic statistics and traffic flow data and applying a multi-criteria criticality analysis, transport networks have been evaluated based on interdiction (population and economic costs) and disaster exposure criticality. To do this, origin-destination (O/D) data points as well as attraction and production factors have been used to calculate traffic flow performance and transport demand between the centroids of Romania's 42 counties. The results have then been overlaid with FATHOM pluvial and fluvial flood risk data for multiple return periods to determine the population's increased travel time and associated economic costs due to a disruption.

**Step 3: Identification and prioritization of critical and exposed transport segments.** The two criticality components—interdiction and exposure—have been kept separate so policy makers can identify whether each transport segment is both critical and flood exposed or critical but not flood exposed or not critical but highly flood exposed. The analysis located several road and rail segments that are both critical and flood exposed; this information is fundamental for carrying out targeted investments and making good use of public funds.

**Figure 34.** Three-step approach for using network criticality for prioritization and schematic overview of analysis

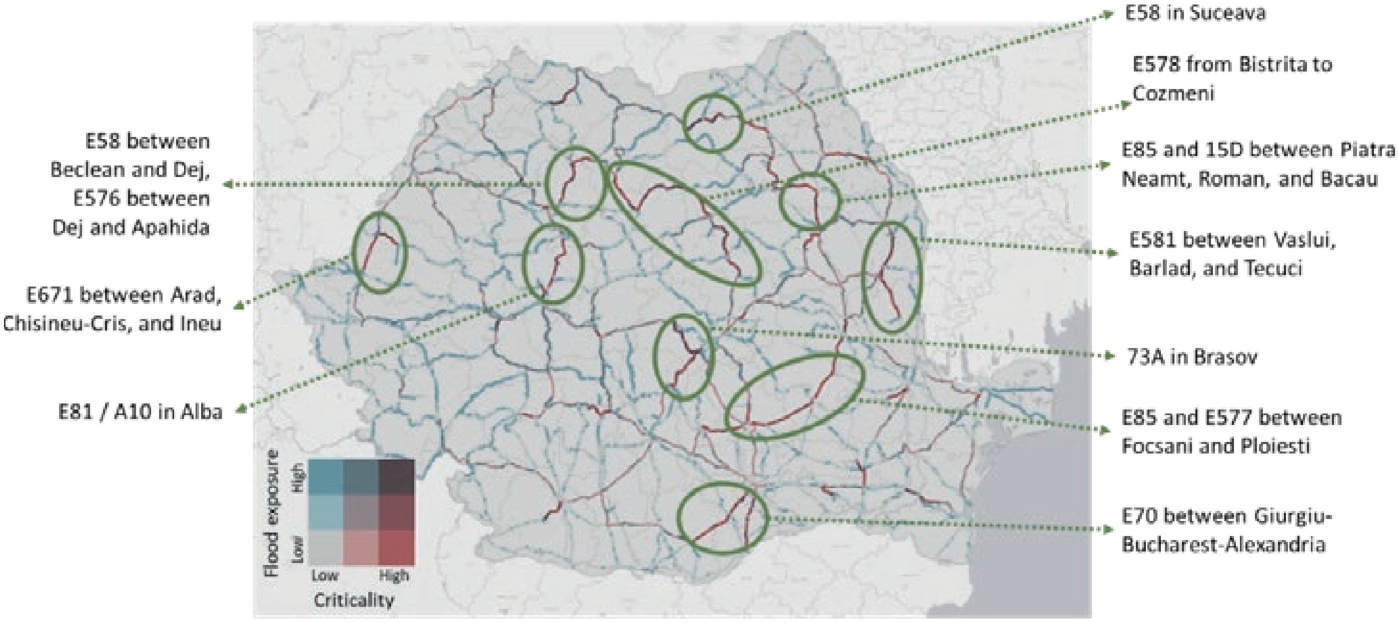



*Source:* World Bank.

## SUMMARY OF FINDINGS

**While several road segments were identified as critical for maintaining the connectivity of intercounty transport activities** (for example, west, east, and north of Bucharest; north of Ramnicu Valcea; northeast of Buzau; and between Ploiesti and Focsani), not all of them are also exposed in case of a 100-year flood event. The results indicate that several road segments in the middle part to the western part of Romania are both critical and flood exposed. For instance, the road segments between Focsani and Ploiesti are exposed to pluvial flooding from runoff. In the northeast part of the country, potential flooding from the Bistrita River makes the segment between Bacau and Roman critical as well. Shorter stretches of critical segments are also found in the western half of the country (see Figure 35 and highlighted road segments).

**Figure 35.** Multi-criteria criticality results for road network's functionality for overall economic activities

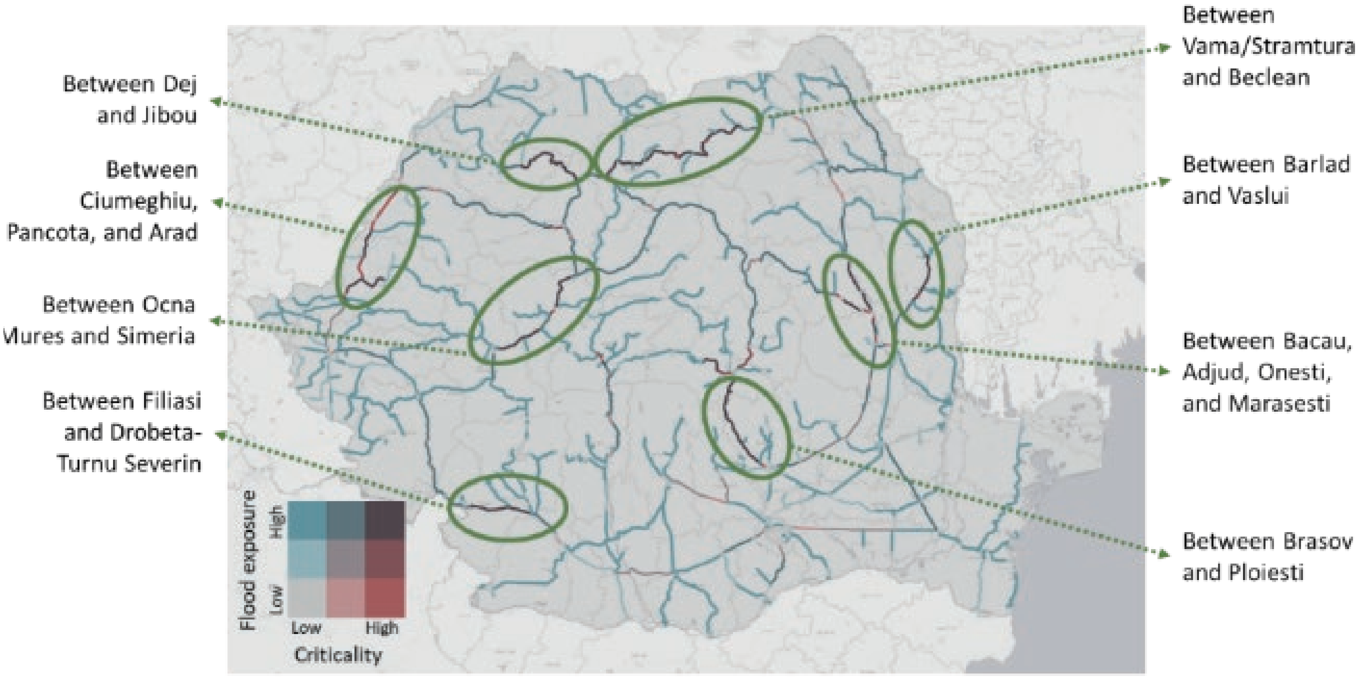



*Source:* World Bank.
*Note:* Some emerging critical road segments are highlighted. The analysis combines interdiction criticality with exposure to a 100-year flood event.

**Overall, disruptions happen not in places where the highest share of transport demand occurs.** By aggregating impacts across all return periods, it was learned that the annual expected increase in economic transport costs due to flood disruption is 5.84 percent. Several counties in the middle and northern parts of the country emerged as the most vulnerable: Maramures, Sibiu, Brasov, and Hunedoara, for instance, can expect an annual increase between eight and nine percent. There are no clear statistical relationships between road transport disruption and socioeconomic vulnerabilities. Five counties—Iasi, Suceava, Mehedinti, Salaj, and Tulcea—have a relatively high fraction of marginalized population and relatively high transport and social vulnerability and can thus be the focus areas of further road transport resilient investments.

**Like the road network, not all critical railway segments are also exposed to floods.** Unlike the road network though, even a small-scale flood event can cause significant disruption on the passenger railway network: a 5-year flood event almost doubles the nationwide economic transport cost (approximately 90 percent increase). The annual increase of economic passenger railway cost due to disruptions is 24.5 percent. Most of the railway segments identified as critical based on an interdiction criticality indicator are also highly exposed to inundation in an extreme 100-year event. See Figure 36 for highlighted rail segments. A set of five counties emerged as the most vulnerable: Maramures, Salaj, Mures, Bistrita-Nasaud, and Harghita. It is also important to highlight that some counties found to be vulnerable to disruptions of passenger rail network are also vulnerable to disruptions of the road network (Maramures, Salaj, Bistrita-Nasaud, Harghita, Alba, and Sibiu) and could thus be focus areas for future rail transport investments.

**Figure 36.** Multi-criteria criticality results for passenger railway network, combining interdiction criticality with flood exposure



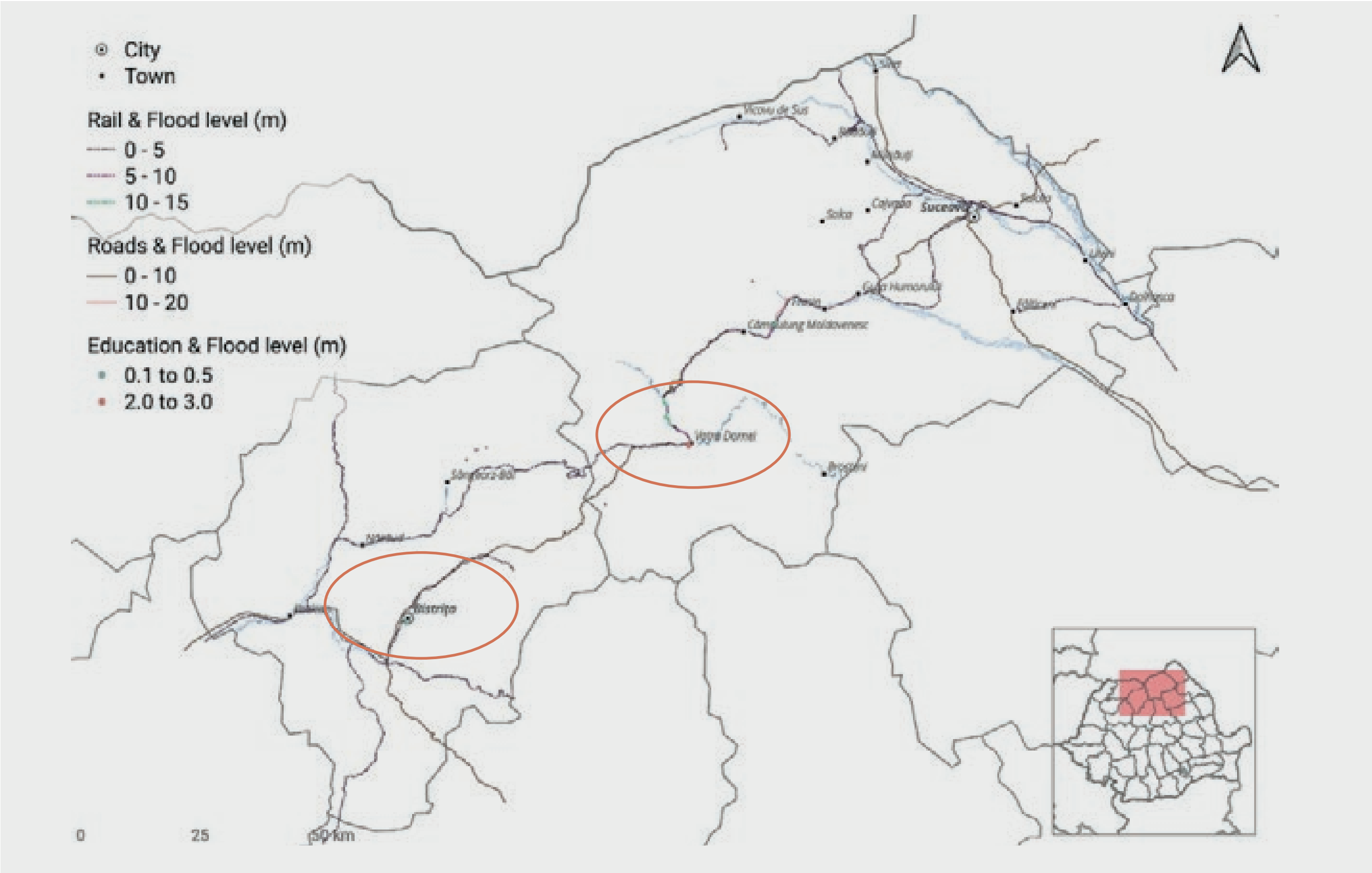

*Source:* World Bank.
*Note:* Some emerging critical rail segments are highlighted.

**Overall, four areas where both the road and railway segments are critical are as follows:**

- Connections between Suceava and Beclean in the north; this includes the E58 in Suceava.
- Around Vaslui: Railway segment between Barlad and Vaslui in the east as well as the E581 in Vaslui.
- Around Alba: Railway segment between Ocna Mures and Simeria, including the E81 and A10 main roads around Alba.
- Railway and road segments between Ciumeghiu and Arad in the west.

**In a further analysis, these critical road and rail segments can be overlaid with the overall flood exposure maps for Romania.** Hereby, the towns Bistrita and Vatra Dornei stand out because its CP assets are not only affected by possible road and rail disruptions, the health care and education facilities also face moderate exposure to 1-in-10-year flood events (see Figure 37).

**Figure 37.** Distribution of education facilities and river flood hazard in the area between Suceava and Beclean, Romania




*Source:* World Bank.

**Besides the identification of strategic road and passenger railway segments as noted above, the Romania case study identified three broad policy recommendations.**

- First, policy makers should consider expanding networks in highly vulnerable areas by constructing new transport segments to ensure the availability of alternative detour segments when the shortest path routes are disrupted.

- The second possibility is making the existing network more disaster resilient and reducing the exposure of critical transport segments, for instance, through improving road drainage, adding more lanes to improve water retention capacity, improved maintenance, or other engineering measures.

- Lastly, CP assets that are near critical road/rail segments and also subject to flood exposure could be prioritized for resilience-enhancing investments/initiatives.

## LESSONS LEARNED AND RECOMMENDATIONS

**For Romania.** The criticality and vulnerability analysis of Romania's road and rail networks has proven to be a viable method to distill recommendations and compare and prioritized planned investments in the transport sector. Moreover, the case study helped uncover additional research areas, for example, marginalized groups, and could be expanded to include further natural hazards or specific type of measures.

**For other countries.** This kind of analysis enables to assess the relative importance of individual road segments to identify the most vulnerable users of infrastructure services. By identifying bottlenecks and vulnerability hotspots, this kind of analysis helps prioritize investments in disaster and climate resilience.

When using the network criticality approach for investments in a national transport network, several general lessons learned can be applied by other countries:

- *Network data.* It is essential to have access to a baseline level of accurate and up-to-date data and develop a comprehensive understanding of the transport network, including its interconnected components and dependencies. Identifying critical nodes helps prioritize investments.
- *Single or multiple hazards/current and future climate scenarios.* This analysis is typically applied in a single-hazard context (such as floods). However, if data are available, it is possible and preferred to conduct a more complex/ comprehensive risk assessment that considers various hazards, vulnerabilities, and potential impacts. A complementary scenario-based analysis may be useful to evaluate additional stressors, disruptions, and emergency situations. Also, to the extent possible, future climate projections could be introduced.[130]
- *Prioritization and monitoring.* While identification of critical sectors provides critical information of prioritized action, as risk is dynamic and evolves, efforts also need to be done to implement and monitor networks performance. Collaboration among different sectors and stakeholders and regular M&E of the transport network's performance and resilience are crucial.

## Croatia - Prioritizing Emergency Preparedness and Response Investments with the R2R Method

**The case study on Croatia demonstrates the application of the global R2R assessment.**[131] R2R is a quantitative method, aligned with international best-practice. It focuses on five key components of emergency and response systems, which are evaluated by assessment participants through 18 criteria, 72 indicators, and 360 attributes. The method, facilitated by an online tool, was used to conduct a rapid and expertise/data-driven self-assessment of the emergency preparedness and response system at the national and city levels in Croatia to understand its key strengths and weaknesses. While R2R was previously applied in several Western Balkan countries as expert review assessment, this innovative application relied on adaptation of this tool to an EU MS country context, visualized through an online tool, and fully using the methodology as a self-assessment by national- and local-level experts/officials working on emergency response and response. The case study shows the potential to use this tool to establish a quantifiable, easily repeatable benchmark to inform prioritization efforts in the next years as well as to monitor progress against planned targets. **This analytical tool can be highly relevant to UCPM members seeking a rapid analysis and understanding of key gaps in preparedness and response that can be focus of further actions and focused investments.**

130 Future climate projections are the subject of the EDPP2 Component 2 report.
131 World Bank. 2017b. *Ready2Respond: Rapid Diagnostic User Guide Emergency Preparedness and Response Systems.* Link.

## BACKGROUND

**Croatia has a diverse hazard and risk landscape, given Croatia's coastal geography and large forest coverage,**[132] **with exposure to various hazards, including earthquakes, floods, and forest fires.** Climate change is expected to have major impacts in Croatia, with an expected increase in intensity and frequency of disaster events and hotter and drier summers. In the past decade, a series of disaster events uncovered Croatia's vulnerability and exposure to significant disaster events. On March 22, 2020, Zagreb was hit by the strongest earthquake recorded in 140 years, with a magnitude of 5.5 on the Richter scale.[133] The earthquake occurred in the middle of a nationwide lockdown due to the COVID-19 outbreak, also affecting COVID-19 testing centers and health facilitates specialized for respiratory diseases. Just nine months after the Zagreb earthquake, on December 29, 2020, Sisak-Moslavina County in Croatia was struck by a 6.2 magnitude earthquake with the epicenter six kilometers outside the town of Petrinja.[134] The damage and losses from both these earthquakes were estimated to be €16.1 billion.[135] Coupled with the impacts of other crises, such as the energy crisis in May 2023, northern Croatia was struck by heavy flooding, breaking 2014 recorded flood levels, which in turn resulted in several landslides. This series of catastrophic events has exposed institutional capacity constraints related to disaster and climate resilience and preparedness.

**To better understand the risks associated to disasters**, an exposure analysis conducted at the NUTS3 level across Croatia helps identify the exposure of assets, energy, and transportation infrastructure, which are critical in DRM. Below is a summary of the main findings grouped by hazard type:

**Wildfire:** Over 76 percent of police and fire stations (a total of 554 buildings) are exposed to high and very high wildfire hazard. A lower proportion of education and health facilities are exposed to this level of hazard—69 percent (315) and 57 percent (95), respectively. Due to the coarse resolution hazard data available for this analysis and omission of facility-level features such as defensive space omitted, this is likely to be a conservative estimate, with localized variations in hazards indicating that fewer facilities are exposed *directly* to wildfire but are nevertheless located in areas that could be affected by this hazard.

- **Landslide:** Few emergency response related assets are in areas of high or very high landslide susceptibility in Croatia—in total, only 88 (7 percent) of the 1,300 assets analyzed. These comprise 29 education facilities, twelve health care facilities, 27 fire stations, and 20 police stations.

- **Earthquake:** Emergency response related assets in Croatia face a high exposure to high-seismic hazards, determined as strong ground shaking (MMI ≥ VI) with a ten percent chance of occurring in a 50-year period, with over 90 percent of assets exposed. Health care facilities face the highest exposure proportionally with 93 percent (156) of facilities exposed. In addition, 414 education facilities (91 percent of the total) are exposed. A similar number of fire stations (418, 89 percent of all fire stations analyzed) are exposed to high hazard while about half the number of police stations (212), representing the same proportion (89 percent), are exposed. Figure 38 displays the length and proportion of road and power line assets that are exposed to high-seismic hazard in Croatia, as determined by the analysis. Over 2,600 km of roads and 8,000 km of power lines in Croatia are exposed to strong seismic shaking intensity (MMI ≥ VI), which amount to 91 and 93 percent, respectively. These figures reflect the situation in Croatia after the series of earthquakes in 2020, which caused significant damage to health and education assets, but do not explicitly consider the seismic resistance of any individual asset of building stock to earthquakes.

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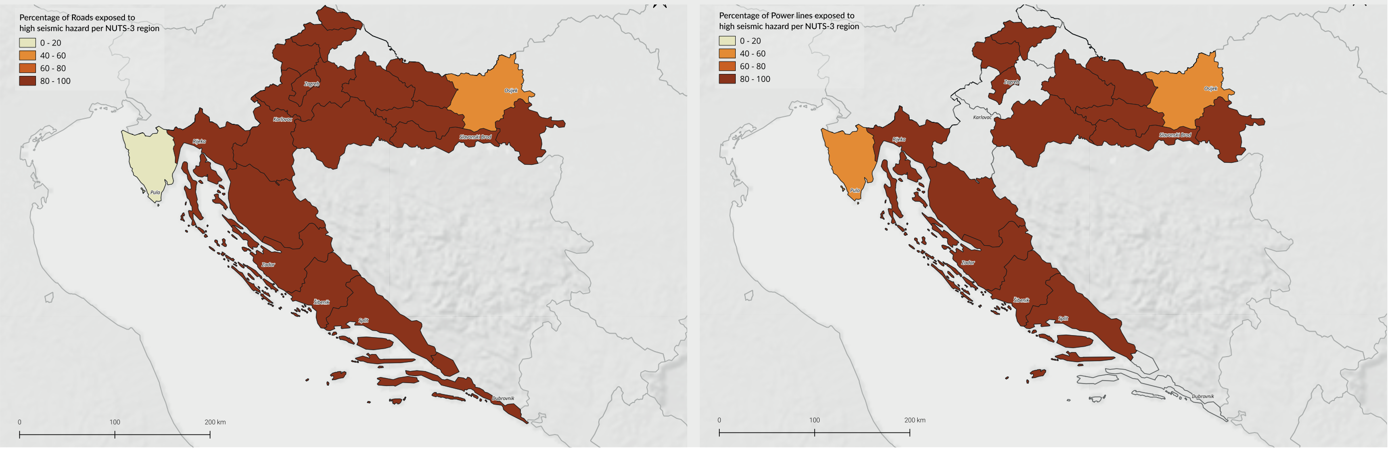
132 Notably, after Slovenia and Estonia, Croatia has the third largest share of forest area of 58 percent (EU average: 43.5 percent).
133 The earthquake resulted in one fatality, 26 injuries, and hundreds of displaced persons.
134 Seven people died, 15 people required hospitalization, and dozens more suffered minor injuries due to the December 29, 2020, earthquake.
135 €11.3 billion for Zagreb and €4.8 billion for Sisak-Moslavina County. It should be noted that €4.12 billion represents the value of damaged physical assets and €714 million refers to losses—see Government of Croatia (2020).

**Figure 38.** Example map of exposure of assets to seismic hazard

**Exposure of emergency response related assets to earthquake: Roads, Croatia** (Percentage of roades exposed to high seismic hazard per NUTS-3 region)

**Exposure of emergency response related assets to earthquake: Power lines, Croatia** (Percentage of Power lines exposed to high seismic hazard per NUTS-3 region)




*Source:* World Bank, as part of EU-wide exposure analysis.

## STEPS IN THE ANALYTICAL PROCESS

**The analytical process of the R2R assessment in Croatia included the following steps:**

**Step 1: Preparatory actions.** The reparation for the R2R assessment involved the translation of the tool into the Croatian language, including verification of terminology (18 criteria, 72 indicators, and 360 attributes) and adjusting it to fit to the European/Croatian DRM context. Consultations with counterparts were held in advance of the assessment to identify internal capacities and existing expertise. The online tool was adjusted accordingly in English and Croatian and surveys for all participants were generated. Each participant's assignment was tailored to his/her expertise to ensure more robust results.

**Step 2: Conducting the R2R assessment.** Online surveys were piloted at the national and local levels with workshops hosted by the Ministry of Interior and the city of Zagreb, respectively. Participants attended the workshops either in person or online, with most of them being able to complete their assignment within 30 min, depending on the number of assigned criteria. After the assessment, a feedback survey was disseminated among the participants.

**Step 3: Generation and evaluation of results.** As participants responded, the results of the assessment were generated and evaluated. A summary of results was provided to the stakeholders within 48 hours after the launch of the assessments.

**Step 4: Setting priorities and identification of research gaps.** Discussions were held with stakeholders to discuss the strengths and weaknesses as well as further identify ways the results can be used, that is, to inform strategic or operational documents and investments planning, whether for singular or regular use.

**Figure 39.** Four-step approach for prioritizing emergency preparedness and response investments as part of a R2R assessment


*Source:* World Bank.

## SUMMARY OF FINDINGS

**The R2R assessment allowed for a rapid yet comprehensive overview and visualization of strengths and weaknesses in terms of national- and city-level disaster readiness and areas of improvement.** The results highlighted the strengths and weaknesses across the five components as well as across all 18 criteria, 72 indicators, and 360 attributes.

**At the national level,** the R2R self-assessment found potential gaps related to critical infrastructure, financial preparedness, information systems (such as GIS and early warning systems), and training/knowledge and internal capacity management. The highest scores related to equipment capacities, particularly urban firefighting, and technical rescue. The results of the assessment suggest opportunities to prioritize DRM planning and capacity building going forward. During subsequent discussions, stakeholders noted ongoing/planned projects which match identified gaps or may reinforce results (for example, development of legislative plans) as well as areas where plans/projects must be refined. The results of the R2R assessment will be further analyzed at the national level, with high-level as well as operational-level internal discussions, to develop priorities moving forward. The preparation of strategic documents, including potentially the *Civil Protection System Development Plan*, is under consideration.

**At the local level,** potential weaknesses were highlighted in crisis communication and early warning systems. Strengths, on the other hand, related to urban firefighting, technical rescue, and emergency response services. Participants also considered strengthening the overall Croatian DRM system at different areas and levels a necessity. The results also highlighted the realities of local-level response, where further cooperation with various entities would be needed at the national level. Local-level authorities plan to conduct further analysis of these results, which will inform an upcoming *Urban Security Strategy for the City of Zagreb.*

**Overall,** both national- and local-level participants recognized that the R2R assessment results can easily be integrated into local- and national-level strategies under development and inform discussions to enable the definition of priorities in the upcoming years. Stakeholders plan to leverage the results at the national level to open a broader discussion with other stakeholders including the EU on how to strengthen the DRM system and address systemic issues. Furthermore, the results uncovered areas where the national and local levels could collaborate closer to strengthen vertical and horizontal institutional resilience. The results may also support planning at the subnational level.

## LESSONS LEARNED AND RECOMMENDATIONS

**The following lessons learned are relevant for both Croatia and other UCPM countries:**

- *Focused and evidence-based decision-making.* The analysis of the gaps and opportunities in the DRM cycle should be a prerequisite for determining the directions and priorities for prevention and preparedness. The R2R methodology can be a useful tool to inform decision-makers about the realities of the DRM system and create an action/operational plan to achieve better impact across all levels (that is, national, subnational, and local). It is noted that the analysis was not supported by the identification of gap-specific studies and/or identification of specific investment plans, but this could be the next step.

- *Smart use of capacity assessments.* Capacity assessments often require both extensive resources and time. A common challenge is that assessments must consider a range of different stakeholder views and it is not always easy to ensure a representative participation. Also, capacity assessments are often conducted by external experts/facilitators which may affect results and sustainability of such exercises. This case study demonstrated that the R2R assessment can be conducted rapidly as a self-assessment, without significant time/resource input, and comprising multiple perspectives from different sectors and expertise. Also, the methodology and online tool present opportunities for conducting such an assessment in a sustainable, easily repeatable manner and linking it to the operationalization/implementation of strategies by allowing to track progress. Results of robust assessments like this can be used for advocacy in prioritizing investments to strengthen the DRM system.

- *Value of engaging different participants.* The assessment generates results which indicate levels of agreement. This is crucial because it is important that decisions are based on an acceptable level of agreement among a broad range of stakeholders. Furthermore, the method and tool can foster broader engagement among key DRM stakeholders and facilitate conversations and collaboration or even help create new links. Disagreement among participants may also be used as a conversation starter and open discussions on why an area scored low or high among certain groups of participants and what can be done to reach a consensus.

- *Value of focusing on expert views.* DRM is dynamic and multifaceted, which should be reflected in prevention and preparedness planning. DRM has a wide range of stakeholders who could inform policy and decision-making from their area of expertise. For example, the R2R analysis allowed participants to answer questions specific to their expertise so they may answer questions from their own technical and operational perspective. This prevents the generation of skewed results.

- *Importance to connect national and local levels.* The methodology provides comparable results and hence also allows to foster cooperation/collaboration across different administrative levels. This could be extremely helpful when assessing capacities at different scales or when seeking to better understand subnational strengths and inter-city or inter-regional cooperation potential. Or more broadly, it could help understand the ability of the overall system to respond in an adequate manner to disasters or localized impacts and assess the systems' overall complementarity and robustness.

- *Objective and subjective lens.* While this approach aims to deliver an objective expert assessment, during the discussion of results, there is also a need to apply a subjective lens to the objectively prioritized findings. The R2R assessment identifies where relative gaps may be in an emergency preparedness and response (EP&R) system, whereas the subjective lens then assesses the willingness of the government to fix the identified weaknesses, thereby increasing the likelihood of investment success.

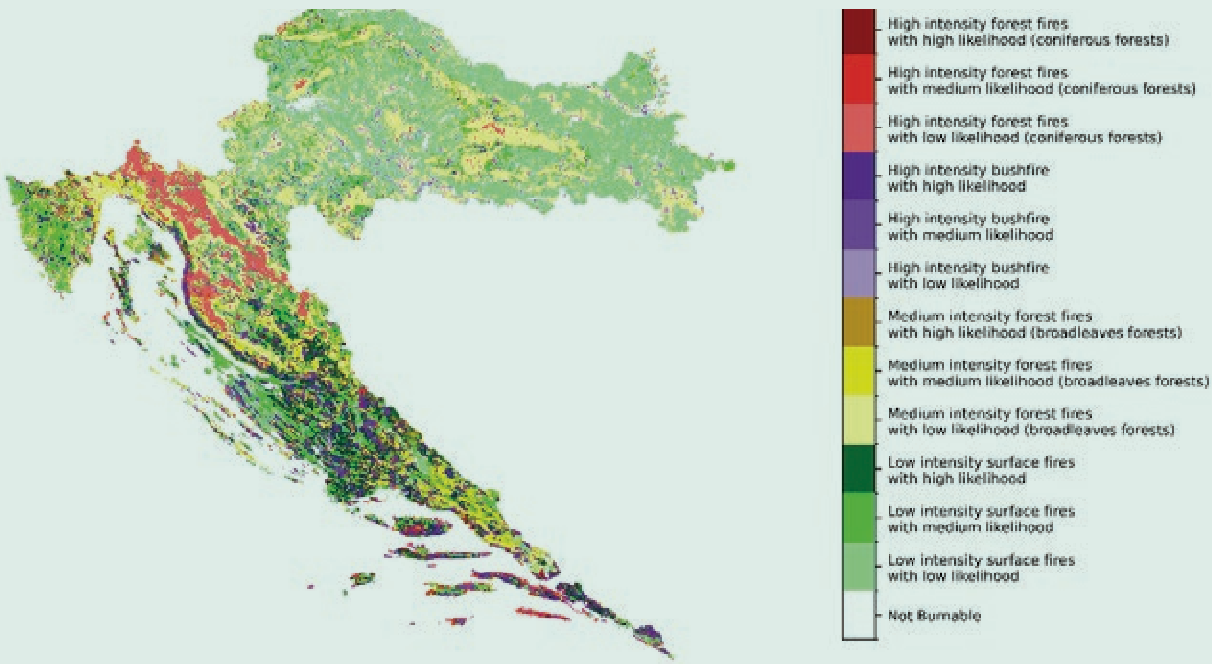
**There is an opportunity to combine the results of the R2R assessment to inform specific scenarios, that is, wildfire scenarios.** Incorporating data and analytics into the R2R assessment process provides decision-makers with a clearer and more effective way forward. This combination of approaches can identify areas where proactive measures can significantly mitigate future risks, save more lives, and reduce the impact on critical sectors and the broader economy. For example, in combination with risk data, a tailored R2R assessment can be considered for key areas at risk of wildfire. An example from Croatia is portrayed in Box 16.

## BOX 16. EXAMPLE OF INTEGRATING FURTHER LAYERS OF DATA

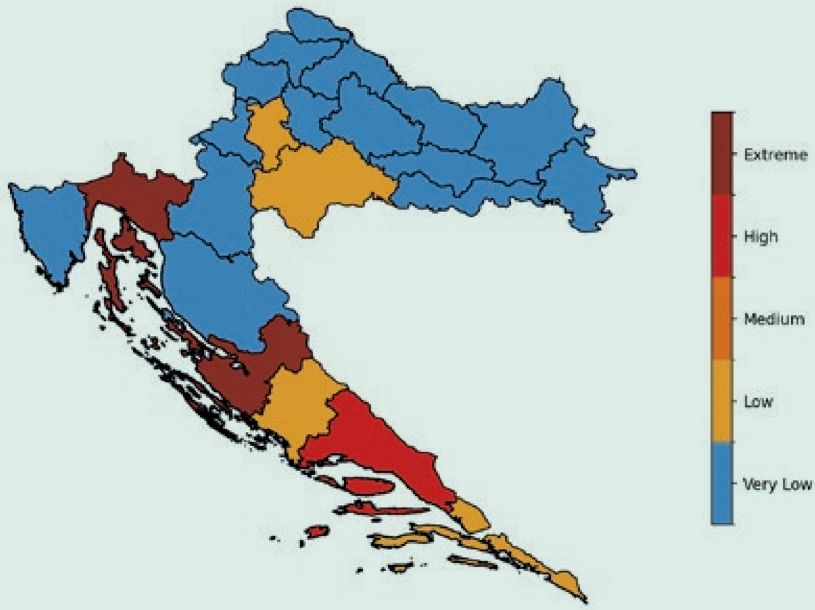
**Enhancing the R2R assessment with additional data and analytics can further support smart and focused decision-making.** R2R assessment can also be adapted to specific hazard scenarios, such as wildfires—a notable threat in Croatia's risk landscape.[136] The rapid wildfire analysis conducted as part of this study, which integrates climate change predictions into risk modeling and combines social vulnerability with coping capacity assessments, is crucial for identifying regions of underinvestment and insufficient capacity. This method can be applied at both the national and local levels. For example, a national R2R assessment might evaluate overall wildfire coping capacities or focus on areas with a higher social risk index, as depicted in Figure 40. The R2R assessment can also be tailored to assess localized, scenario-based impacts, which can guide future investment strategies to enhance capacity in regions with high social risk index and poor R2R assessment results. Alternatively, Croatia could identify areas with lower social risk and positive R2R assessment results, where less investment is needed. For example, considering Figure 40, Croatia could conduct a localized R2R in its southern and coastal regions, where the risk of wildfires is currently elevated. These areas are characterized by a dry and warm climate, coupled with a relatively low capacity to cope with such disasters. The risk is expected to remain high, necessitating a focus on areas most vulnerable to wildfires. In contrast, the northern region currently possesses a stronger coping capacity, as a result of a higher density of fire stations. However, as climate change progresses, altering weather patterns with decreased precipitation and increased temperatures, even areas currently considered lower in risk are likely to experience heightened wildfire threats. Therefore, it is imperative to bolster wildfire preparedness measures across the country, with an emphasis on adapting to these evolving conditions. In this way, data integration leads to a more nuanced and informed approach to wildfire risk prioritization, resulting in a strategic allocation of resources.

**Disasters exacerbate existing vulnerabilities, highlighting the importance of social vulnerability in planning at both the national and local levels.** Integrating social vulnerability data with R2R assessments can reinforce pre-disaster planning efforts, such as resource pre-positioning, identification of areas with the greatest needs, training, and targeted communication campaigns that account for the wildfire social risk index, as portrayed in Figure 40, which identifies areas at increased risk due to higher social vulnerability. This comprehensive perspective allows policy makers to prioritize regions most prone to severe wildfires with significant consequences, thus enabling more efficient resource allocation.

**Figure 40.** Croatia Wildfire Social Risk Index




136 Government of Croatia. 2019a. "Disaster Risk Assessment for the Republic of Croatia" [Procjena rizika od katastrofa za Republiku Hrvatsku]. Main Working Group Croatian National Platform for Disaster Risk Reduction. Link.

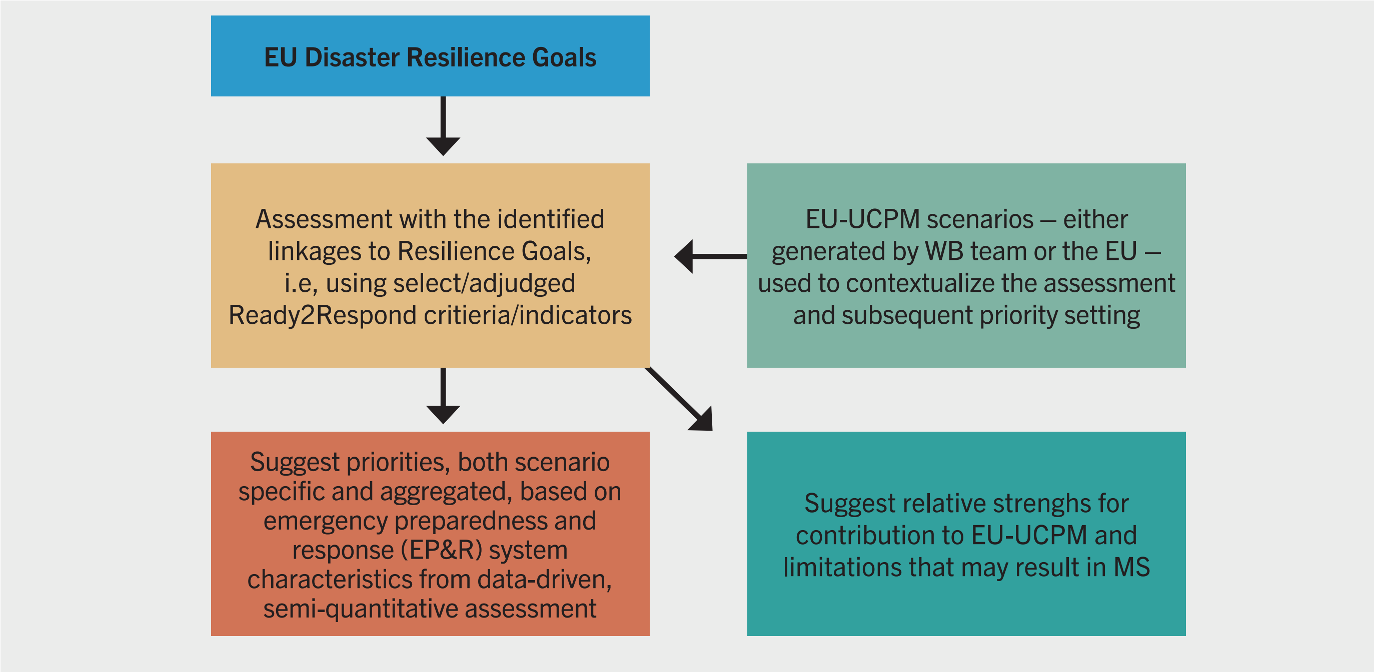



*Source: World Bank based on CIMA analysis.*

**Applicable for broader EU UCPM.** The results of the R2R assessment could also be useful for the wider UCPM and EC to support the Government of Croatia to set priorities in the current and next MFFs, particularly related to strengthening resilience through different programs. By providing countries with opportunity to make use of such self-assessments at the national and city levels, as was conducted in this case study, the EU may have a better understanding on how policies and projects can better support the local-level readiness through urban resilience programs. Given the multifaceted nature of the DRM cycle, and the multiple actors involved in creating a resilient society, this type of self-assessment can provide a clear breakdown of different aspects identified in the DRM cycle to better tailor assistance.

**Understanding the strengths and weaknesses of the emergency response and preparedness system of UCPM member and PSs is crucial for reaching the objectives of the UCPM and EU DRGs.** By assessing the UCPM's capabilities and gaps through such assessment, the EC can identify the areas of support and collaboration needed to enhance overall EU resilience. More broadly, the R2R assessment may also be used to highlight gaps at the EU level in crisis response, where, for example, technical assistance programs could be tailor-made to scale up EU-wide resilience and preparedness. Knowledge of strengths, for example, may be utilized for the identification of best practices and successful strategies that can be shared across the EU through the UCPM Knowledge Network and beyond and can promote mutual learning and effectively preparedness measures. In parallel, recognizing weaknesses helps the EU target areas that require improvement and prioritize resource allocation. Through this understanding, the EU can facilitate capacity-building initiatives, provide technical assistance, and foster knowledge exchange among EU MSs. By leveraging UCPM member and PSs' strengths and addressing their weaknesses, the EU can foster a collaborative and coordinated approach to resilience, ultimately strengthening the EU as a whole in responding to and recovering from disasters. This approach could be conducted at the scale and manner that would generate comparable results and/or results that can inform policy decisions at various levels. Figure 41 provides an overview of such an approach for the R2R methodology; however, other methodologies could also be considered, as noted in Chapter 2.

**Figure 41.** Example - linking DRGs and adapted R2R approach




*Source:* World Bank.

## Key Insights Across Case Studies

**The case studies provide practical steps of how to adopt focused and smart decision-making, in alignment with EU frameworks and national strategic considerations.** Like the existing examples from Europe outlined across Chapter 4, these new case studies also highlight the need and value of evidence-driven, context-specific approach to investing in DRM, benefits of access and use of risk information, and importance of an interdisciplinary collaboration and commitment of decision-makers. They go however beyond the actual prioritization process by providing broader policy recommendations for improving resilience, aligning with national and EU objectives, and enhancing critical infrastructure.

**The case studies underscore the importance of data availability and reliable risk assessments for informed decision-making.** Across the case studies, there is notable challenge related to data collection and quality of data. While data-poor environments do not preclude conducting simplified analysis, even for those, additional time is needed for even basic data collection. The EU-wide exposure mapping shows the importance of understanding the exposure of emergency response assets to various hazards. While this was beyond the scope of the EU-wide exposure analysis, multi-hazard risk assessments are crucial because they enable smart investments that consider all relevant hazards simultaneously. Also, while this was not possible under these case studies, the results highlight the need to analyze the risk of cascading effects of disasters, especially in cases where the functionality of critical assets is compromised.

**Across the case studies, there is a notable importance of interdisciplinary collaboration and stakeholder ownership.** Consultations with different technical experts and stakeholder input as part of all the steps and then specifically on the decision criteria and their weighting are essential. Related to this is also the need to improve long-term planning practice for DRM investment across many countries, which does not systematically take into account prioritization tools and engagement of diverse experts to address complex hazards and emphasize collaboration between various sectors and stakeholders.

**A challenge that presented itself as part of the case study analysis is the fact that considerable time may be needed to conduct individual prioritization tools.** The more approaches are included in the prioritization framework, the more time may need to be invested in the development of the framework. It is therefore important to understand thoroughly the individual capabilities and outputs of each approach to draw up an optimal selection of approaches that leads to comprehensive results and avoids duplication of efforts.

# 5. Summary and Recommendations: time for action = time for focused and smart investments

**Focused and smart investments are crucial for strengthening Europe's critical sectors against disaster and climate risks and tackling accelerated warming and heightened climate extremes.** Recent catastrophic events in Europe have exposed vulnerabilities in emergency response services and critical sectors, including hospitals, schools, and fire stations, underscoring the urgency to scale up investment in prevention and preparedness.

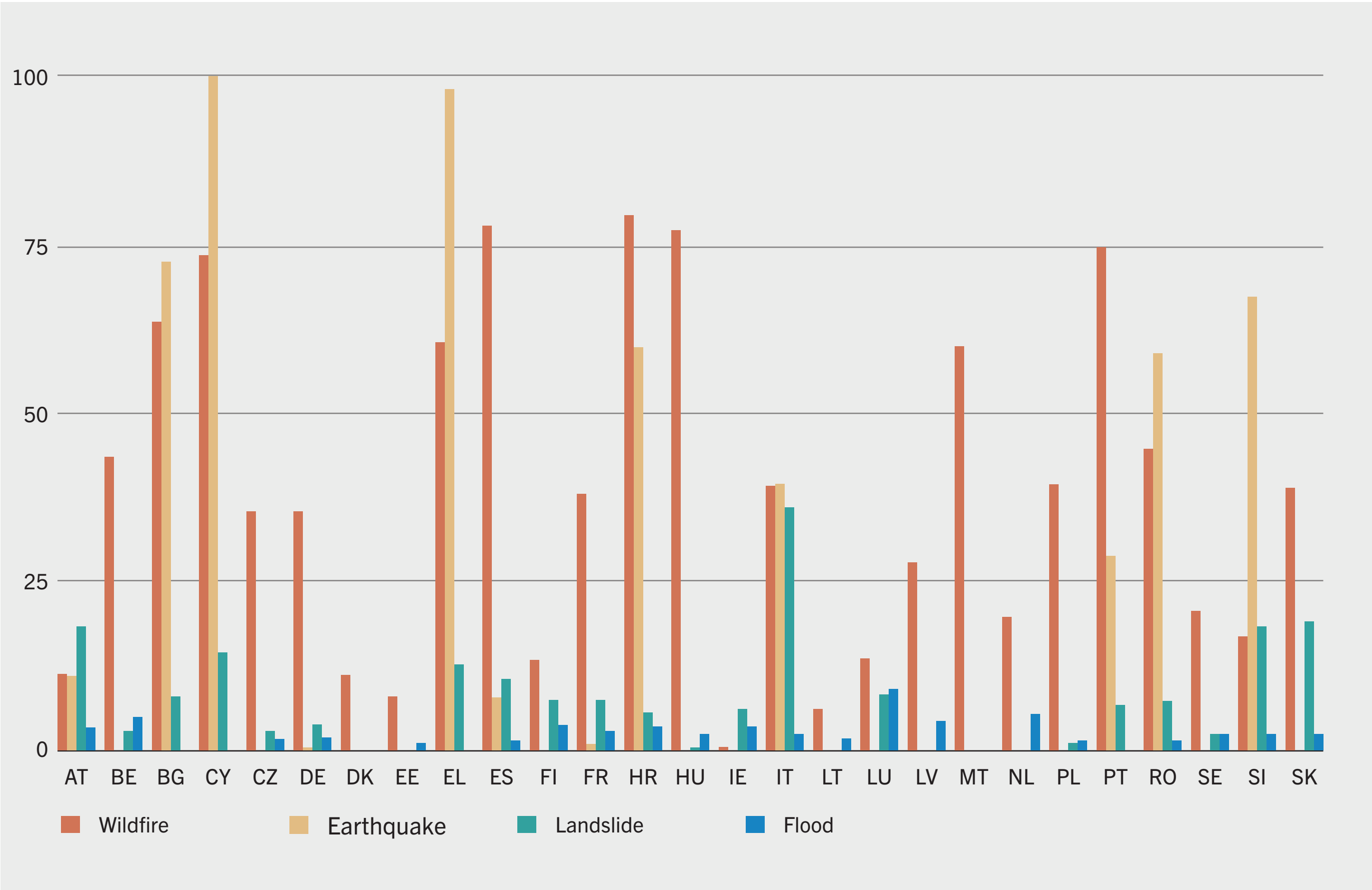
**Addressing existing knowledge gaps, this report provides guidance to decision-makers and practitioners on adapting focused and smart approaches to enhance the disaster and climate resilience of critical sectors across Europe.** By identifying EU-wide hotspots where critical assets are exposed to multiple hazards and offering tools and examples for risk-informed investment planning, the report aims to inform both EU-wide policy discussions and national/subnational investment strategies and efforts. Through the utilization of seven analytical tools and lessons learned from over 30 examples and five case studies, decision-makers can make better-informed decisions and prioritize impactful actions within resource constraints.

## Focus on Critical Sectors

**This report shows that a substantial share of emergency response-related assets in Europe are exposed to multiple hazards, including wildfire, flood, earthquake, and landslide.** Though locating these assets in areas of high hazard can make response more efficient, it also poses significant risks. The EU-wide hazard exposure assessment identifies hotspots where these critical assets are exposed to multiple hazards and therefore potentially subject to damage, which in turn could disrupt disaster response. It is notable that in half of the MSs, fire stations are exposed to high levels of wildfire, landslide, flood, or earthquake (Figure 42). Across all MSs, almost 3,500 emergency response-related assets are exposed to flooding of greater than half a meter in a 1-in-10-year river flood. Eight MSs (Greece, Cyprus, Bulgaria, Croatia, Slovenia, Romania, Italy, and Portugal) have over 35 percent of their emergency response-related assets exposed to a potentially damaging seismic hazard. Eleven EU MSs have hundreds of assets in areas of high landslide susceptibility, and in large countries—namely Italy, Austria, France, and Germany—this can mean thousands of assets exposed. Related specifically to road and power line infrastructure, EU-wide mapping shows that around half of all EU MSs have over 80 percent of roads and 70 percent of power lines exposed to high wildfire hazard.

**To determine the right combination of measures for addressing these exposures, more granular studies need to be combined with prioritization tools and approaches.** Immediate follow-up analysis might include portfolio vulnerability assessments or susceptibility studies. Full-fledged disaster risk assessments for multiple hazards, including climate scenarios and considering asset-level and local protection infrastructure, complemented by network criticality assessments, estimations of costs and benefits, or other types of analytics, as demonstrated in this report, would be needed to support investments in resilienWce building in individual assets. With improved information, risk-informed investments could beW made to promote resilience and overall emergency response capabilities.

**Figure 42.** Proportion of fire stations exposed to high levels of each assessed hazard




*Source:* World Bank.

## Smart Prioritization for Disaster and Climate Resilience of Critical Sectors

**It has been well established that the resilience of critical sectors requires a solid governance (institutions and regulation) and prioritized investments, including upgrading and maintenance.**[1] Yet, investments are lagging due to restrained financing, lack of incentives to strengthen resilience and avoid disruptions, and lack of high-quality data, tools, and capacities.[2] Decision-making processes that integrate prioritization frameworks can help identify the most impactful actions in a resource-constrained environment and help scale up investments in risk reduction and preparedness of critical sectors, including those providing civil protection (CP) and emergency response.

**This report illustrates that prioritization of focused and smart investments is an indispensable process to identify impactful, targeted, and cost-effective improvements, given potentially substantial needs and limited resources.** Prioritization frameworks provide a transparent and systemic way to focus attention and efforts on specific issues or locations and make informed decisions. They ensure that activities are aligned with strategic objectives at the national or EU level, impacts are maximized, and essential risks are not overlooked.

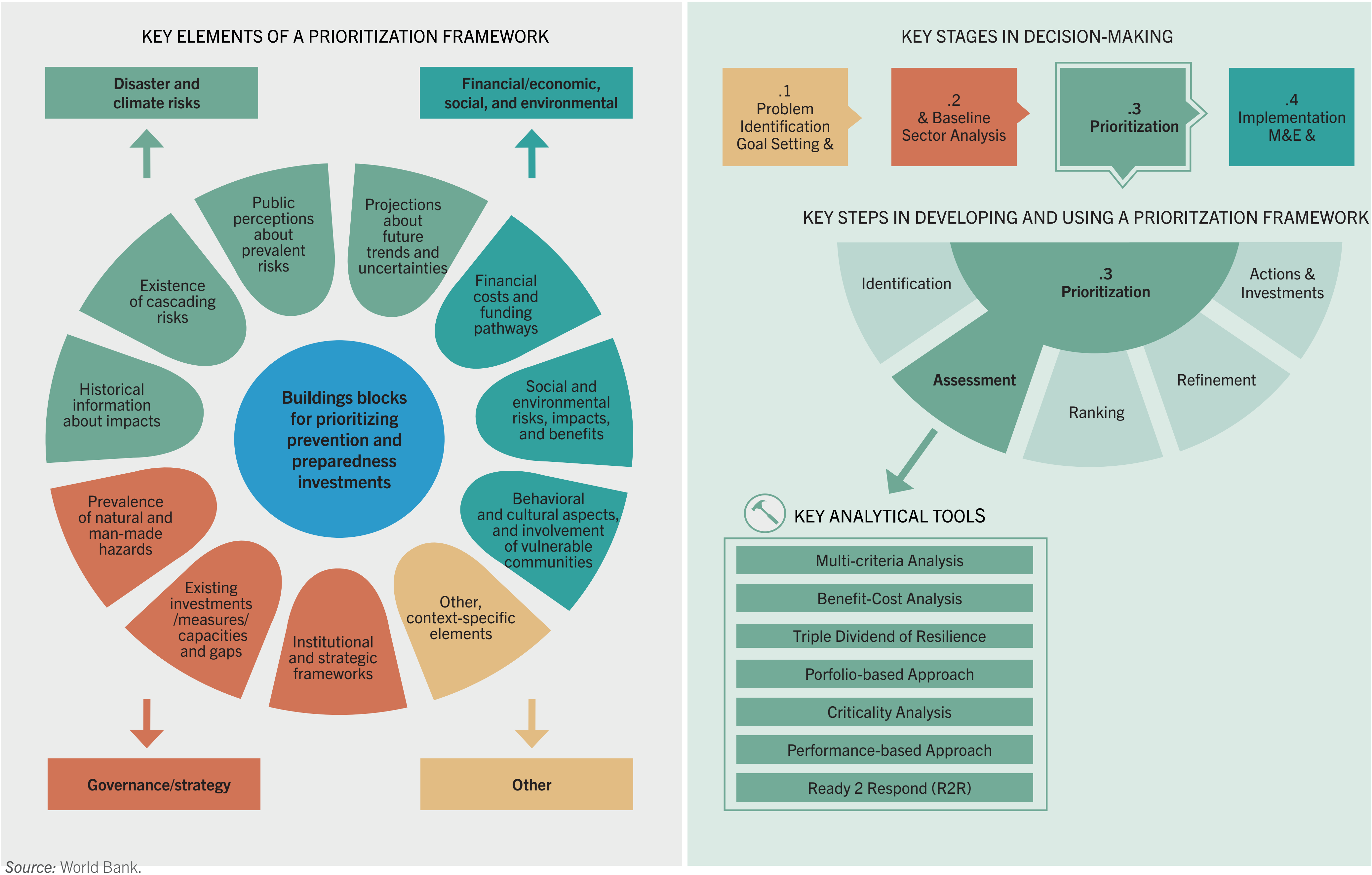
**Decision-making needs to be tailored to the geographic, climatic, socioeconomic, and other conditions considering the specific policy or Investments.** This means that the different phases within the prioritization process and the specific steps within the prioritization framework will vary depending on the context and complexity of the identified problem or challenge. Factors such as data availability, capacity of the responsible planning and implementing entities, financial resources, and ability to include participatory and inclusive approaches will also influence the selection and implementation of prioritization strategies.

**The identification and prioritization of DRM investments follows four key stages:** (I) problem identification and goal setting; (II) baseline and sector analysis; (III) development and use of a prioritization framework; and (IV) implementation and M&E. Each stage is crucial for ensuring effective decision-making and resource allocation throughout the prioritization process.

**Within this four-stage decision-making process, the development and use a prioritization framework (stage III) follows separate steps.** They generally include (1) identification of assessment criteria, (2) assessment weighting of investment options based on the criteria, (3) ranking or scoring of options, (4) refinement of prioritization results with expert feedback and additional analysis, and (5) development of an investment action plan or roadmap and its implementation (see Figure 43).

1 Hallegatte, Rentschler, and Rozenberg 2019.
2 Hallegatte, Rentschler, and Rozenberg 2019.

**Figure 43.** Process and considerations for prioritizing DRM investments




*Source:* World Bank.

**In developing and implementing a prioritization framework, it is crucial to consider several key elements.** These include governance structures, disaster and climate risk data, financial, economic, environmental, and social aspects, and context-specific factors. These correspond to the specific context of each sector or region. By accounting for these multifaceted considerations, the prioritization process becomes more robust, balanced, and adaptable, fostering resilience and sustainability in the face of evolving threats and uncertainties.

**Several analytical tools and approaches are available for prioritizing investments in critical sectors, each addressing different elements and criteria.** Despite data limitations, these tools can be used effectively, either rapidly or through gradual analysis. The report describes seven analytical tools, highlighting their respective strengths and weaknesses, and presents over 30 successful prioritization examples across different countries, along with five case studies demonstrating analytics in data-poor environments. The most applied approaches include MCA, portfolio- and performance-based approaches, TDR, criticality analysis, R2R methodology, and BCA.

**The approaches are not mutually exclusive, and in fact they are often complementary and can be used in combination to maximize the effectiveness of prioritization efforts and robustness of results.** By leveraging multiple analytical tools simultaneously, decision-makers can gain a more comprehensive understanding of risk factors, resource constraints, and investment opportunities within critical sectors. This integrated approach enables a holistic assessment that considers diverse perspectives and optimizes decision-making for enhancing resilience and mitigating disaster risks. Some approaches could also become tools for conducting EU-wide capacity reviews of gaps and weaknesses, tracking progress toward higher-level objectives, or even guiding the preparation of funding schemes. Highlighted analytical approaches are provided in Box 17.

**BOX 17.** SUMMARY OF KEY RELEVANT APPROACHES

- **Multi-criteria analysis (MCA)** can identify priorities within strategies and investment plans across different levels of decision-makers. In recent years, it has been used by several EU MSs for developing national DRM plans. In Greece and Bulgaria, this approach made it possible to bring together different priorities across different hazards and sectors; the results informed the identification of subsequent programs, projects, and priorities, such as those under the countries' respective NRRPs.
- **Triple Dividend of Resilience (TDR) approach** expands the traditional BCA approach and considers three types of benefits: avoided losses when disasters strike, stimulated economic activities and innovation arising from reduced risks, and generated socioeconomic and environmental co-benefits. Whether for a portfolio of assets or individual programs/projects, investment decisions can be greatly enhanced by using a TDR approach; the Croatia case study applied this approach.
- **Portfolio-level assessments** can clarify the condition and risk levels of a portfolio of assets (such as fire stations, schools, or hospitals). Existing lessons learned from Romania and a new case study in Croatia show the potential of using this kind of analysis and associated results for prioritizing integrated investments in upgrading/reconstruction of CP and education buildings at high risk.
- **Criticality analysis** can improve the understanding of the resilience of networks—such as transport, energy, or health—and impacts of shocks within it. The Romania case study shows how information on flood risk and criticality can be used to better target investments.
- **Performance-based approaches** can complement different types of analysis by focusing on specific performance indicators. The Bulgaria case study used a performance-based analysis to integrate considerations of heat and wildfire risks into the prioritization framework circumscribed by the national DRM plan.
- **The Ready2Respond (R2R) approach** can quickly yet systematically illuminate the key strengths and weaknesses of CP and emergency response systems by covering key capacities, namely (a) legal and institutional framework, (b) personnel, (c) facilities, (d) equipment, and (e) information. In the Croatia case study, the self-assessment was used to generate a rapid yet comprehensive overview of the strengths and weaknesses of the preparedness and response system at the country and city levels.

**Existing examples of successful prioritization of prevention and preparedness investments collectively emphasize the value of a risk-based and targeted approach to investment planning.** They include several analytical approaches to supporting prioritization frameworks that are particularly relevant for the context of CP and emergency response-related sectors. Table 11 summarizes existing country examples as well as the new case studies developed as part of this report, showing how different analytical tools may be used for different hazards.

**Table 11.** Key examples and case studies of prioritization tools per hazard covered in this report

| | | |
|---|---|---|
| Multi-hazard | **Existing examples:** | Both **Bulgaria** and **Greece** used a semi-quantitative, multi-hazard MCA approach to link their respective national-level risk assessments and climate considerations and prioritize a range of measures proposed by different line ministries and other stakeholders related to various sectors and natural hazards. **Albania** also applied a multi-hazard prioritization assessment (for floods, earthquakes, and landslides) to build the resilience of the national road transport networks based on several vulnerability and economic criteria. |
| Multi-hazard | **Case study:** | **The Croatia case study** showed that multi-hazard exposure is high, with a significant percentage of CP assets exposed to high levels of two or three hazards. The application of a global R2R assessment provided a comprehensive overview and visualization of strengths and weaknesses in terms of national and city-level disaster readiness. It also highlighted areas of improvement that are particularly relevant for data-poor environments. |
| Wildfire | **Existing examples:** | **In Portugal**, a wildfire risk assessment and scenarios helped identify exposure of buildings, communities, and natural areas as well as their capacity to adapt to changing circumstances. The analysis fed into the national fuel management plan and highlighted vital priorities to safeguard the most vulnerable communities and promote national-level landscape management programs. In **France**, a risk-based approach and network criticality analysis were used. This work drew on an impact assessment and tabletop input from stakeholders to understand the effects of forest fires on interconnected critical infrastructures (electricity, roads), considering different climate scenarios. It also produced a methodological framework. |
| Wildfire | **Case study:** | **The Portugal case study** analyzed benefits and costs of the existing and potentially adjusted scope/focus of the SVSP program. Spatial analysis of areas most at risk, along with analysis of prioritization schemes, showed potential for increased benefits. The information from the analyses can guide future decisions about resource allocation and wildfire risk reduction, increasing the impact of the program and thus resilience of communities. |
| Floods | **Existing examples:** | The Delta Program in the **Netherlands** is a relevant example of a multistage risk-based and participatory BCA approach that incorporates NBSs. A mix of risk-based and participatory approaches has also been successfully applied in **Ireland,** where a multisectoral assessment was conducted and prioritization of interventions was based on simple, participatory approaches considering nonmonetary, broader benefits of flood risk reduction measures·b |
| Floods | **Case study:** | **The Romania case study** used network criticality analysis to identify the relative importance of individual road segments and the most vulnerable users of infrastructure services. By identifying bottlenecks and vulnerability hotspots, this kind of analysis helps prioritize investments in disaster and climate resilience. |

| | |
|---|---|
| **Extreme heat** | **Existing examples:** |
| | In **Italy**, a combination of participatory planning and multi-criteria methodology, which considered environment, social, climate, economic, landscape, and health safety,[c] was applied to guide the city government of Catania in implementing a new city greening and resilient development program. In **Austria**, a scenario-based approach used an urban climate model to assess the benefits and costs of white measures (increased reflectivity of sealed surfaces) and green measures in three cities: Mödling, Klagenfurt, and Salzburg. |
| | **Case study:** |
| | **The Bulgaria case study** demonstrated the use of risk information and of key performance indicators (KPIs) to help evaluate the effectiveness of considered DRM measures for extreme heat and wildfire. The KPIs identified in this study are typical and exemplary for prioritization at the national level, and they could also be applied by other countries for monitoring of national DRM plans and strategies. |
| **Earthquake and associated Landslides** | **Existing examples:** |
| | In **Romania**, a portfolio-wide assessment of seismic risk combined with information on building criticality helped prioritize investments worth over €332 million to improve seismic safety, modernization, and energy efficiency in emergency response-related assets (fire, police, and gendarmerie stations; schools) and fund nonstructural measures (training, equipment, and so on). Benefits were calculated, in line with the TDR approach, and were found to exceed investment costs. |
| | **Existing examples:** |
| | In **Italy,** a scenario-based criticality analysis was conducted as part of the INFRARISK project in Italy. A stress test was performed that modeled the effect of low-probability/ high-consequence seismic hazard events and the associated landslides. This analysis helped identify the network elements that were most affected by the hazards and thus need to be prioritized when implementing seismic risk reduction measures.[d] The impact of the scenarios was measured in both direct costs (the network repair costs) and indirect losses (the disruptions to the transportation system and network users, with traffic analyses conducted through the use of NEXTA traffic simulation software[e]). |
| | **Case study:** |
| | **The Croatia case study** applied a rapid portfolio assessment approach, demonstrating that robust analysis can be done even with limited data. The case study shows positive BCR for interventions for seismic safety in combination with energy efficiency. |

*Source:* World Bank compilation.
*Note:* BCA = benefit-risk analysis; BCR = benefit-cost ratio; CP = civil protection; MCA = multi-criteria analysis; R2R = Ready2Respond.
a. Alcasena, F., et al. 2021. "Assessing Wildfire Exposure to Communities and Protected Areas in Portugal." *Fire* 4 (4): 82. Link.
b. EC. 2021d. *Current Practice in Flood Risk Management in the EU.* Brussels, Belgium: EC. Link.
c. Sturiale, L., and A. Scuderi. 2019. "The Role of Green Infrastructures in Urban Planning for Climate Change Adaptation." *Climate 7* (10): 119. Link.
d. Clarke, J., R. Corbally, and E. Obrien. 2016. *INFRARISK Del 8.2—Case Study Results*. Link.
e. Network EXplorer for Traffic Analysis (NEXTA) is an open-source graphical user interface (GUI) that facilitates the preparation, post-processing, and analysis of transportation assignment, simulation, and scheduling data sets.

## Key Challenges and Opportunities Going Forward

**To advance policy change and scale up focused and smart investments in resilience in critical sectors, particularly those related to emergency response, there is a need to tackle existing challenges and leverage opportunities identified through this report.** The challenges and opportunities—listed below—are aligned with the five key policy recommendations highlighted in the Executive Summary.

Challenge: **Lack of consistent political commitment for critical sectors beyond the immediate disaster response phase.** While policy makers and the broader public focus on the provision of critical services during a disaster or immediately afterwards, there is no sustained political commitment for strengthening the resilience of critical sectors; this absence is reflected in existing gaps in strategic, policy, and investment frameworks. Prioritizing focused and smart investments often involves making difficult trade-offs between competing needs and objectives. Balancing short-term priorities with long-term resilience objectives is thus crucial and demands strong political will and policy support.

Opportunity: **Spotlight resilient critical sectors—including the CP and emergency response sectors—across policies, development strategies, and investment plans.** Resilient critical infrastructure and services need to be explicit policy priorities across the policy/strategic investment frameworks at various administrative levels, including EU, national, and subnational, to enable commitment of funds and scale-up of actions, in line with relevant responsibilities. There are opportunities to highlight critical sectors under the UCPM (1313/13), and in achievement of the DRGs, and under the CER Directive (2022/2557), among others.

Challenge: **Data and information on critical sectors are incomplete.** While this report shows the feasibility of conducting rapid data collection or using existing data for initial (phased) analysis, it also acknowledges that some gaps prevent deeper or faster analysis. The EU-wide exposure analysis noted gaps in, for example, the granularity of data for some hazards, such as wildfire and landslide, major information gaps when it comes to exposure to current and future conditions, and compound or cascading risks. Apart from information through OpenStreetMap, comprehensive and consistent data sets with geospatial information on CP and emergency services across EU MSs are not available. Case studies also show data gaps related to infrastructure vulnerability, social vulnerability factors, and functionality of networks or systems.

Opportunity: **Promote and fund research into critical sectors to fill existing data and knowledge gaps.** As shown in the EU-wide exposure results, there is a great need to invest in deeper analytics (exposure mapping, probabilistic modeling, vulnerability/criticality assessments), especially in areas with the greatest exposure to multiple natural hazards under current as well as future climate conditions, for example, southern and eastern Europe. More research is needed on intensification of hazards (flood, wildfire, extreme temperature, drought) as a consequence of climate change as well as on compound risk considerations for specific sectors or groups of sectors. Finally, there is a particular need to better understand the condition of critical sectors' infrastructure assets and their capabilities to provide emergency services in case of different hazard events, including compound events. This is especially true for those EU MSs where many assets are exposed to multiple hazards.

Challenge: **Investment decisions for critical sectors are not systemically informed by disaster/climate risks, do not consider a range of dimensions, and do not follow approaches that can maximize results.** Recent examples of failures of critical infrastructure show that investments in critical sectors are often ad hoc, with insufficient consideration of disaster and climate risks or broader development outcomes. The benefits and costs of investments in disaster and climate resilience are not systematically quantified, and consolidated information about the benefits and costs of prevention and preparedness investments in these sectors is scarce. The case studies also show gaps in the technical expertise needed for prioritization of investments in disaster and climate resilience.

**Opportunity: Take focused and smart investment decisions to maximize the benefits of investing in resilient critical sectors.** Building on existing and new research, risk information needs to be part of prioritization in development strategies, development plans, and investment plans concerning critical infrastructure and services, including those providing emergency response. At the program level, decision-makers should use tools and methodologies to guide their decisions. Identifying the most exposed or critical assets, networks, or services—and understanding related benefits and costs—can help maximize multiple co-benefits of investing in disaster resilience. Prioritization frameworks need to fit local context and specific objectives and needs, and they should be flexible and adaptable to account for both the dynamic nature of risks and the complexity and variability associated with climate change. Initial or rapid approaches can be conducted in data-poor environments, which can then lead to more robust and comprehensive prioritization frameworks. Stakeholders will also need the capacity for designing and using such frameworks to ensure that entities beyond traditional CP agencies are well equipped to address challenges.

**Challenge: The damage to critical sectors caused by recent events, and the common weaknesses across many countries, point to significant gaps in investments in emergency response-related sectors.** While funds are available through national and EC budgets, the uptake does not match the increasing risk arising from climate change. Comprehensive data are lacking, however; as seen in recent disaster events, many emergency response-related infrastructure assets are in urgent need of upgrading or reconstruction. Only a few dedicated programs seek to upgrade high-priority at-risk critical sectors in a prioritized manner that considers various dimensions and links the effort to broader disaster and climate resilience efforts. While funding sources are available, the criteria and eligibility are not always clear and may not be conducive to smart and prioritized investments. Moreover, few countries track budget on prevention and preparedness, and such comprehensive data are not available at the EU level, either.

**Opportunity: In line with political commitments and confirmed priorities, commit funds for upgrading, replacement, and maintenance and operation within critical sectors and then track results.** Given their central role in securing public safety, authorities need to increase their current levels of spending on ex ante prevention and preparedness measures, including upgrading of critical sectors at risk, ensuring proper operations and maintenance, carrying out robust evaluation and monitoring, stress testing, and regular updating of assets and capabilities in line with new research. In parallel, it could be useful to review existing funding streams to identify opportunities for better use of funds for disaster and climate resilience, with a specific focus on CP and emergency response sectors. There is also an opportunity to improve tracking of current levels of prevention and preparedness. Improved data on spending, along with examples of successful approaches, programs, and projects, can contribute to a virtuous cycle of positive change across different administrative levels.

**Challenge: Gaps in coordination and collaboration among stakeholders can hinder investments in critical sectors.** For example, poor maintenance or lack of investment critical sectors is frequently linked to limited national or subnational budget allocations and complex funding arrangements between different levels of stakeholders. There are also gaps in the technical skills within public authorities, and public initiatives are often disconnected from initiatives led by academia or the private sector.

**Opportunity: As disaster and climate resilience is a cross-cutting and all-of-society effort, strengthen collaboration vertically and horizontally, both through and in support of the above efforts.** Society's resilience can be further reinforced by promoting a preventive culture and meaningfully involving a broad set of stakeholders—across national borders, across administrative levels, within relevant countries, within the public, private, and civil sectors, and across critical sectors and academia. There are many examples of relevant initiatives. Going forward, improved collaboration can help speed up and improve preparation, planning, and implementation of investments in prevention and preparedness and in this way scale up impactful programs to increase disaster and climate resilience. Closer partnerships with academics and researchers could also decrease technical capacity gaps within public institutions.

## Recommendations and Next Steps

**A range of stakeholders can contribute to scaling up focused and smart investments in resilient critical sectors.** Table 12 illustrates the role of different stakeholders in guiding future steps. To facilitate the uptake of recommendations, Table 13 breaks down some of the key recommendations presented above by time horizon (short term: 1–2 years; medium term: 3–4 years; long term: 4–10 years). It should be noted that the recommendations focus on select emergency response-related investments that may be relevant at the national or subnational level. A summary of relevant recommendations for EU-level institutions is presented following Table 13.

**Table 12.** Stakeholders' contribution to resilience of critical sectors

| | LEGISLATION, POLICY, STRATEGY | PROGRAMS, ALLOCATIONS, DECISIONS | INVESTMENTS AND ACTIONS | MONITORING PROGRESS | RESEARCH AND INNOVATION | ENGAGEMENT, COLLABORATION |
|---|---|---|---|---|---|---|
| **EU institutions** | √ | √ | | √ | √ | |
| **National institutions** | √ | √ | √ | √ | √ | |
| **Subnational institutions** | | √ | √ | √ | √ | |
| **Private/ business sector/ industries** | | √ | √ | √ | √ | √ |
| **Academia, research and development** | | √ | √ | √ | √ | √ |
| **Civil society sector** | | √ | √ | √ | √ | √ |
| **Communities** | | | √ | √ | | √ |

*Source:* World Bank.

**Table 13.** Suggested steps to strengthen resilience of critical sectors over the short, medium, and long term

| TIME FRAME | SUGGESTED STEPS |
|---|---|
| **Short term** (1–2 years) | *Strategies*: Review existing strategies/plans related to economic or spatial development, investment planning, DRM, critical sectors, and so on to understand potential strategic gaps in considering disaster/climate risks and resilience of critical sectors; initiate an enhancement process to address these gaps.<br><br>*Data*: Review existing key analytics—such as national risk assessments or hazard-specific risk management plans—to understand potential data gaps and commence research to address these gaps. Depending on the risk profile, conduct risk assessments for specific hazards (such as wildfires or extreme heat) or combinations of hazards or specifically focus on risks for select critical sectors.<br><br>*Prioritization*: Conduct analysis at the national or subnational level (for example, rapid portfolio review, risk assessments, single/multiple hazards risk assessment, and criticality analysis) for relevant assets (that is, portfolio, type of critical sectors assets, and so on) to understand the key challenges and data/information gaps for prioritized critical sectors assets, such as fire and police stations, emergency response/operations centers, education and health care facilities, transportation, information and communications technology, power utilities, and/or other types. Identifying hotspots can be a first step in deciding about future steps and investments.<br><br>*Focused and smart investments*: Review ongoing investments/programs/decision frameworks related to addressing the gaps, including links between investments in disaster resilience, modernization and functionality upgrades, and broader CCA/mitigation efforts, to understand how investments are being prioritized/selected, the potential for introducing prioritization tools, the levels of financing committed/used, and opportunities of co-benefits. Utilize smart technologies as part of the data collection and prioritization process to ensure results are robust, are well informed, and mitigate risk of uncertainty as much as possible.<br><br>*Collaboration*: Review existing structures/arrangements and dedicate funds to engage relevant stakeholders in the design/implementation of investments. Review opportunities to engage the private sector in the scaling up of resilience of critical sectors, starting with key sectors. |
| **Medium term** (3–4 years) | *Strategies*: Update strategies/plans integrating new disaster/climate risk information in line with national and international frameworks, strategies, and commitments, such as NDRMPs, SFDRR, 2030 Agenda, EU DRGs, and so on, to facilitate cost-effective and meaningful scale-up of investments in prevention and preparedness.<br><br>*Data*: Continue to improve the quality, granularity, and usability of data and information relevant to risk reduction, prevention, and preparedness investments. Make non-sensitive data accessible and provide training to officials and other stakeholders on the use and creation of relevant date. Explore new technologies and foster research in key areas in line with existing and emerging risks.<br><br>*Prioritization*: Adopt an integrated, flexible, and multi-criteria approach for prioritizing DRM-focused investment decisions. Design a prioritization framework to be flexible and adaptable with a long-term perspective, based on the specific needs and vulnerabilities of critical sectors-related assets. Consider thereby the dynamic nature of risks; local geographic, climatic, economic, and social conditions; changing political priorities and sector-specific issues; and the variability of impacts associated with climate change. Allow for updates and inclusion of new knowledge and data. Review and maximize opportunities for linking the DRM and climate change agendas and invest in greening of national and subnational critical sectors-related sectors.<br><br>*Focused and smart Investments*: Adjust and/or develop new dedicated programs at the national and subnational levels with allocated funds to address identified gaps (for example, further research, assessment of feasibility of various solutions, and structural investments). Support the rehabilitation/reconstruction and modernization of critical assets/services in a prioritized manner. Develop a robust M&E framework at the national/subnational level and regularly track the implementation and outcomes of prioritized investments, transparently publishing information related to strengthening of resilience and other aspects (such as adaptation, mitigation). This step is critical to increase availability of information and the quality and scale of risk reduction, prevention, and preparedness investments. |

| TIME FRAME | SUGGESTED STEPS |
|---|---|
| | *Collaboration*: Establish and invest in mechanisms/arrangements to foster collaboration between officials/stakeholders related to the above activities and create an environment conducive to knowledge exchange and collaboration for stakeholders from various administrative levels, the private sector, academia, development partner organizations, and local communities. Based on reviews, prepare/facilitate public-private partnerships that bring together government agencies, businesses, and local communities to design, finance, and implement critical sector programs and projects. |
| **Long term (4–10 years)** | *Strategies*: Regularly review/evaluate/update operational arrangements and mechanisms; share lessons and results with relevant stakeholders.<br>*Data*: Continue to fund research and data sharing; continue to explore new technologies and new methods that can inform decision-making.<br>*Investments*: Continue to invest in updating, regular inspection, and maintenance of critical assets; review results and evaluate; share lessons and expand them to other types of assets. Maximize opportunities for linking the DRM and climate change agendas and invest in greening of national CP and emergency response-related sectors.<br>*Collaboration*: Regularly review and build new partnerships/initiatives and strengthen coordination horizontally or vertically. Foster community-based organizations and initiatives to enhance local resilience and response capabilities. |

*Source:* World Bank.
*Note:* CP = civil protection; DRM = disaster risk management; EU = European Union; M&E = monitoring and evaluation; NDRMPs = National Disaster Risk Management Plans; SFDRR = Sendai Framework for Disaster Risk Reduction 2015–2030.

- **At the EU level, the above recommendations also offer opportunities for future actions related to strategies, data, and information collection; tracking of investments in DRM and CCA; and improved use of funds for more impactful investments in disaster and climate resilience.**

- **Related to strategies and investment planning**, there is a need to further strengthen the policy focus on disaster and climate resilience across all major EU funding instruments, with a specific focus on prevention and preparedness of critical sectors and to promote good practice in prioritization frameworks across EU MSs to further improve of investments. For example, the EU's Cohesion Policy already requires MSs to have national risk assessments and national DRM plans; prioritize measures in proportion to the risks and their economic impact; and consider capacity gaps, effectiveness, and efficiency. This approach could be explored for other policy areas, or it could be deepened to include a greater focus on critical sectors and encourage dedicated action plans/funding programs and so on to scale up investments in prevention and preparedness in line with national and international frameworks, strategies, and commitments (for example, Sendai Framework, EU DRGs, 2030 Agenda, and so on).

- **Related to data and analytics,** it is important to continue fostering EU-wide research on key hazards, multiple hazards, and climate projections and make data available to countries and the broader public. The EC is making strong efforts in this regard, including through the JRC and its several flagship research projects, and this study benefited greatly from publicly available data sets produced with the EC's support. There are many other opportunities to continue generating and sharing disaster and climate risk information, including through the upcoming European Climate Risk Assessment and other initiatives.

- **Considering prioritization frameworks**, there is a need to foster knowledge exchange on this topic across EU MS and administrative levels, in part by sharing good practices, providing training, and offering access to relevant expertise. There are also opportunities to advance the tracking of prevention and preparedness spending across various EU policy areas and instruments and conduct quantitative and qualitative analysis (using, for example, the TDR approach or other methods) as part of evaluations. Dissemination of results can help improve the availability of information as well as the quality, prioritization, and scale-up of risk reduction, prevention, and preparedness measures.

- **Related to investments,** the EC can use its policies, programs, and initiatives to promote linking of the DRM/CCA agenda to improve broader multi-hazard resilience across critical sectors. For example, seismic risk reduction investments provide opportunities to integrate net-zero energy upgrades (to reduce operation costs in connection with the greening of CP), functionality upgrades (to improve performance and capacity), gender considerations, and so on.[3] The EC's energy efficiency funds or the Renovation Wave could explicitly promote integrated or smart investments that provide multiple co-benefits, including protection against disaster risks and considerations under the Critical Entities Resilience Directive.

**Finally, related to collaboration**, the EC can continue to foster research, information sharing, and collaboration across subnational, national, and EU levels to address disaster and climate resilience in a coordinated manner. For instance, at the EU level, tools for self-assessment or technical/peer reviews can help the EU understand its use of funds for disaster and climate resilience, including gaps and opportunities specifically related to key hazards or critical sectors. These efforts may be conducted through the existing DG ECHO peer review program or technical assistance programs or through other initiatives.

**In summary, the time is ripe for action to improve the disaster and climate resilience of critical sectors**. Tools and examples are available for decision-makers and stakeholders across different levels to make use of these and scale up their investments in prevention and preparedness, so that communities across Europe not only withstand but thrive in the face of the ever-evolving climate landscape, securing a sustainable future for generations to come.

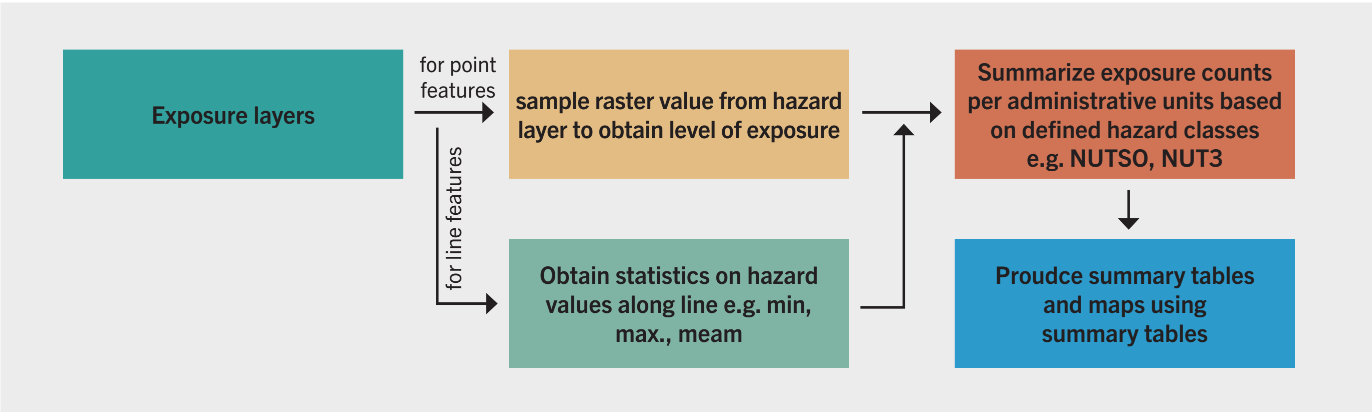
3 Under the 2014–2020 MFF, EU MSs lacked funds for combined seismic and energy upgrading of structures, as seismic upgrading was not included in available EU funding and seismic risk mitigation was not sufficiently prioritized at the EU level. For example, with the aim of maximizing the use of funds, Croatia made the decision to undertake only energy renovation; the concern was that parallel seismic upgrading would slow down the process, complicate implementation, and jeopardize the implementation of EU funding. The 2021–2027 MFF allows the combined use of energy efficiency and seismic interventions, but limitations remain in technical knowledge as well as the capacity of the market to provide suitable solutions.

# ANNEX 1: Additional Information on Exposure Analysis

## Methodology

**The exposure assessment is conducted with spatial analysis using exposure data and hazard data from the open-source GIS, QGIS**. The analytical process is summarized in Figure 44.

**Figure 44.** Analytical steps taken in exposure assessment




**Asset-level exposure data describe the location (latitude, longitude) and use type of each asset.** Generally, the data used do not include construction attributes, which limits our ability to estimate asset damage levels using these data sets, without making further assumptions on construction.

**EU-wide hazard data are used to describe distribution of maximum expected hazard intensity for each of the analyzed hazards**: flood (flood depth, m); earthquake ground shaking (peak ground acceleration, g); wildfire (fire danger, index values); and landslide (susceptibility, index values). Each asset is exposed to some level of hazard; to identify exposure hotspots, a threshold has been chosen for each hazard, for which we count assets exposed to 'high' hazard.

### SINGLE-HAZARD EXPOSURE ANALYSIS

The analytical process, repeated for each asset type and hazard, is as follows:

**Step 1:** Obtain exposure data (sources listed in Table 1). Convert to vector format if required. Load into GIS software.

**Step 2:** Obtain hazard data (sources listed in Table 15). Convert to raster format if required. Load into GIS software.

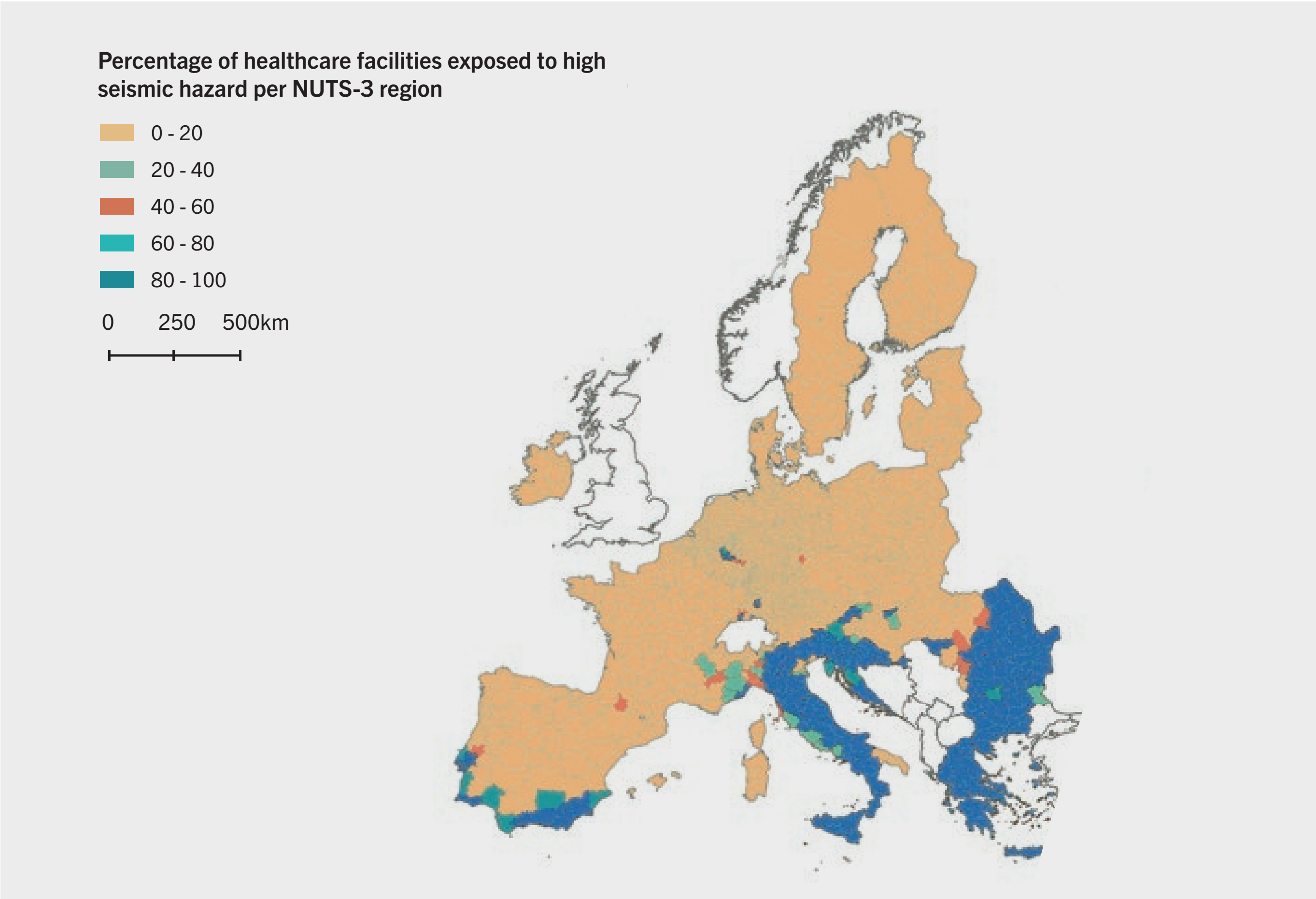
**Step 3:** Apply *spatial overlay* methods, using QGIS tools such as sampling raster values or intersections, to overlay the exposure data onto the hazard data, ensuring that the data sets use the same spatial projection to ensure correct alignment. Spatial overlay adds a new field to the attribute table of the asset vector layer. For each asset, the hazard intensity value occurring at that location is recorded, with some variation according to asset type:

1. Point asset features add the value of the hazard raster grid cell within which the point is located. When using vector hazard data, spatial joins and intersections of hazard and asset data were used to obtain hazard value.

2. Polyline asset features add the maximum, minimum, and mean value of the hazard grid cell for each line segment.

**Step 4:** Export the aggregated asset counts from the asset data attribute table, grouping by NUTS administrative unit (using GISCO 2021). The exported table shows the number and proportion of assets in a defined range or class of hazard intensity, per NUTS unit. This table can be used to produce a choropleth map (units shaded to represent number or proportion) to show exposure hotspots, such as Figure 45.

**Figure 45.** Choropleth map example




*Data Sources:* Healthcare facilities (GEM, 2021), Education facilities (GEM, 2021), Seismic hazard (European Seismic Hazard Map 2020, EFEHR), Administrative units (GISCO)

*Source:* World Bank.

**Step 5:** Export the asset attribute table without grouping. This table can be used to map the location of individual assets and the hazard values associated with that location, to show which individual assets are exposed to each hazard and clustering of assets. Asset points can be overlaid onto hazard data to visualize the distribution of assets and hazard together as shown in Figure 47.

**The hazard thresholds used in Steps 4 and 5 are set at a level to determine what is referred to in this analysis as high or very high hazard.** The selection of thresholds and choice of hazard maps are based on expert judgment. As such, these are subjective, and adjustments would be reflected in changing estimates of assets exposed. The data sources and thresholds used are outlined below and in Table 15.

- **Landslide.** Five classes provided in the original hazard data are used directly with no further adjustment: "1: very low hazard, 2: low hazard, 3: moderate hazard, 4: high hazard, 5: very high hazard". Assets with values of 4 or 5 are considered as being exposed to high hazard.

- **Wildfire.** Five classes are defined in line with the approach taken in the JRC Pan-European Wildfire Assessment. However, we have computed the wildfire hazard, as a function of three base layers (two fire danger layers and the burnable fuel layer) used by the JRC, rather than using the wildfire risk index, which already accounts for the presence of exposure and therefore does not represent a hazard layer. The matrix in Figure 46 was used to classify each cell according to the combination of fire danger based on thermal anomalies and fire weather, and then any cell with less than 40 percent burnable fuel was given a value of 'very low'. Assets with wildfire values of 4 or 5 are considered as being exposed to high hazard in this analysis.

- **Earthquake.** An EU-wide probabilistic seismic hazard map was used from the European Seismic Hazard Model 2020 (ESHM20), providing PGA for each cell, with a probability of ten percent in 50 years (a 1-in-475-year return period), which is used as standard in seismic engineering and hazard analysis. The PGA values were aggregated to seismic intensity values using the corresponding PGA ranges defined by the United States Geological Survey (USGS), to assign each cell a value on the MMI scale.[1] This analysis defines high hazard as having a value of MMI VI or above. MMI VI is classified as strong shaking causing light damage and corresponds to PGA of 11.5 percent g.

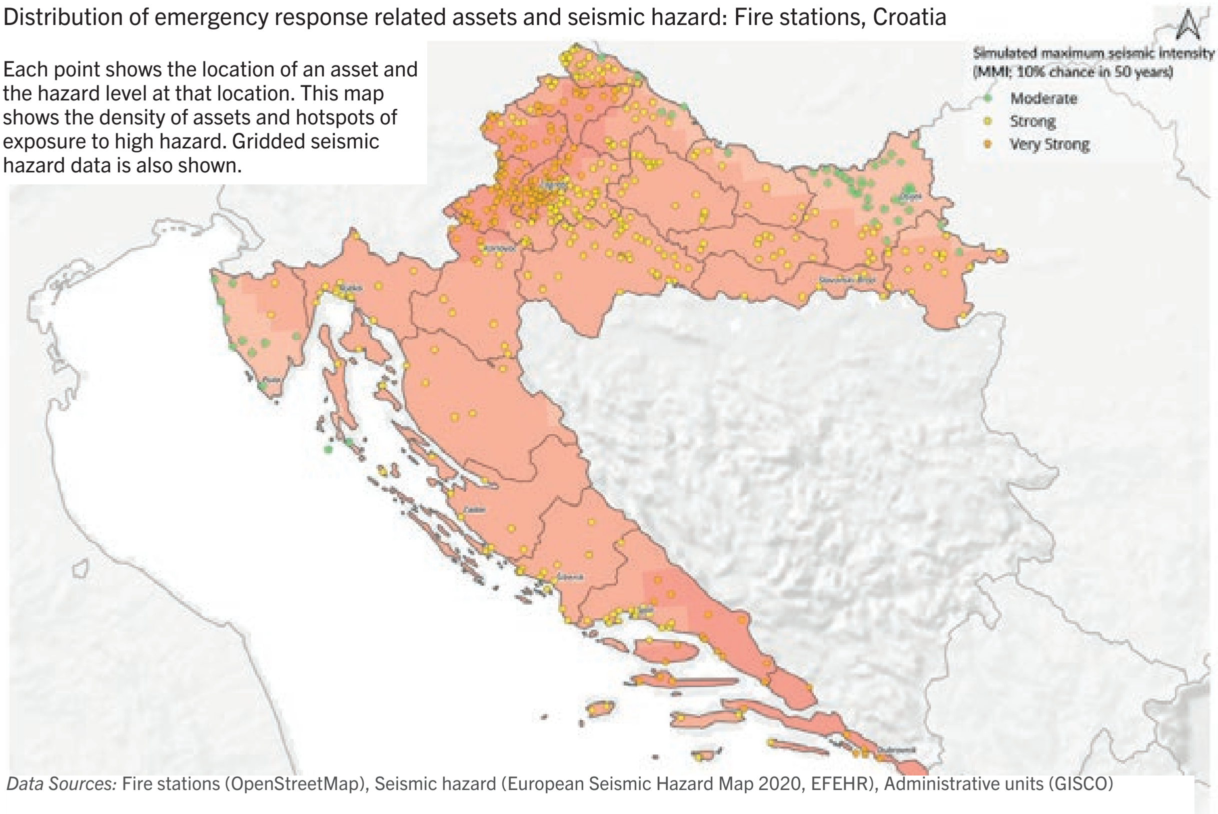
- **Flood.** River flood hazard maps from Dottori et al. (2016)[2] are used to provide estimated flood depth per return period. In this analysis, we selected RP10, to estimate exposure to frequent flood events, and the threshold defined for high hazard is a depth of 0.5 m—anything above this depth is considered high hazard, owing to the increased potential for damage beyond this depth.

1 United States Geological Survey. ShakeMap Documentation. Link.
2 Dottori, F., L. Alfieri, A. Bianchi, V. Lorini, L. Feyen, and P. Salamon. 2016. *River Flood Hazard Maps for Europe - Version 1*. EC, JRC [Dataset] PID: Link.

**Figure 46.** Wildfire danger matrix used to classify wildfire hazard in this analysis

| Danger by thermal anomalies (%) | Danger by fire weather: 0–20 | 21–40 | 41–60 | 61–80 | 81–100 |
|---|---|---|---|---|---|
| 0–20 | VL | VL | L | L | M |
| 21–40 | VL | L | L | M | H |
| 41–60 | L | L | M | H | H |
| 61–80 | L | M | H | H | VH |
| 81–100 | M | H | H | VH | VH |

**Figure 47.** Individual asset map example




*Source:* World Bank.

## MULTI-HAZARD AGGREGATION

**Using the same asset data set to assess exposure to each hazard enables** an assessment of how many of those hazards each asset are exposed to and which assets are exposed to a high level of more than one hazard.

**By creating a spatial join on each asset ID in the data sets produced in the single-hazard analysis,** the level of hazard for each analyzed hazard has been compiled into one file. Applying the same hazard thresholds as for the single-hazard exposure assessment, a count has been made for each asset, to count the hazards which exceed the defined threshold. This assigns each asset an associated number between 0 and 4, denoting whether the asset is exposed to high levels of zero, one, two, three, or four of the analyzed hazards. These numbers are summarized at the different spatial resolutions (Europe-wide, MS, and NUTS3) used in the analysis.

## DATA SETS

Where possible, the hazard and exposure (asset and population) data used are consistent across the EU and from EC sources. All data sources are provided in Table 14 (exposure data) and Table 17 (hazard data), which also describes the thresholds used to define high hazard.

**Table 14.** Exposure data used in this exposure assessment

| ASSET TYPE | SOURCE DATA SET | NOTES |
|---|---|---|
| **Police Stations** | OpenStreetMap via Geofabrik extracts | Extracted from OpenStreetMap by the World Bank team (25.12.2022) |
| **Fire Stations** | OpenStreetMap via Geofabrik extracts | Extracted from OpenStreetMap by World Bank (25.12.2022) and reviewed against data shared by Croatia: Croatian Firefighting Association and the Ministry of Interior's Civil Protection Directorate |
| **Power line** | OpenStreetMap via Geofabrik extracts | Extracted from OpenStreetMap by World Bank (25.12.2022) |
| **Road network** | Main Transport Networks (Europe) - (UNECE) | Data from web map illustrating the results of the work of the UNECE Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Node |
| **Education facilities** | All EU MSs: Data set created for EU-wide risk assessment EDPP Phase 1 project (World Bank and European Commission 2021a) | Created using OpenStreetMap geolocated data with additional national level statistics to create a modeled distribution of missing assets (GEM Foundation 2021) |
| | Croatia: Croatian Firefighting Association and the Ministry of Interior's Civil Protection Directorate | Not used in analysis; used to assess suitability of OpenStreetMap data |
| **Health care facilities** | All EU MSs: Data set created for EU-wide risk assessment EDPP Phase 1 project (World Bank and European Commission 2021) | Created using OpenStreetMap geolocated data with additional national level statistics to create a modeled distribution of missing assets (GEM Foundation 2021) |
| | Romania: General Inspectorate for Emergency Situations (GIES) | Not used in analysis; used to assess suitability of OpenStreetMap data |
| | Croatia: Ministry of Health | Not used in analysis; used to assess suitability of OpenStreetMap data |

*Source:* World Bank.

**Table 15.** Hazard data used in this exposure assessment

| HAZARD | SOURCE DATA SET | DATA SET URL | PROCESS/THRESHOLDS |
|---|---|---|---|
| **Wildfire** | JRC EFFIS regional wildfire danger maps (risk viewer)<br><br>Layers developed by JRC as part of the Pan-European Wildfire Risk Assessment<br><br>(The fire *risk* layer is not used) | Fire danger by weather (FWI-30 days): Days with high-to-extreme fire danger by weather (FWI ≥ 30) - uncertainty aggregation of the model's runs: median value<br><br>Fire danger by thermal anomalies: Wildfire danger by observed frequency of thermal anomalies (MODIS/VIIRS) with thermal anomalies ranked against their expected association with wildfires (lower ranking for other vegetation fires) - uncertainty aggregation of the model's runs: median value<br><br>Potential burnable land proportion: Proportion of land which contains burnable vegetation fuel, derived from vegetation classification in CORINE Land Cover maps | Two fire danger layers (index values 1–100) combined into one hazard map (equal weighting approach). Output hazard map is classified as very low to high hazard.<br><br>Combined hazard map masked using proportion of burnable area (≤40 percent of a cell potentially burnable assigned to very Low hazard. All other cells retain classified danger)<br><br>Produced five classes: 1: very low hazard, 2: low hazard, 3: moderate hazard, 4: high hazard, and 5: very high hazard |
| **Landslide** | European Landslide Susceptibility Map version 2 (ELSUS v2) | Landslide susceptibility levels at continental scale derived from heuristic-statistical modelling of main landslide conditioning factors and landslide location data | The five classes provided in the susceptibility map are used in the analysis:<br><br>1: very low hazard, 2: low hazard, 3: moderate hazard, 4: high hazard, and 5: very high hazard |
| **Earthquake** | European seismic hazard map from the European Seismic Risk Model 2020/EFEHR | Peak Ground Acceleration for 1-in-475 year return period (10 percent chance in 50-year period) | Data set provides maximum PGA value per grid cell for the return period. Nine PGA classes were defined to use in the analysis. These align with MMI units. The threshold used for high hazard is MMI VI. |
| **Flood** | River flood hazard maps for Europe - version 1 | 10-year return period flood hazard maps (10 percent annual probability) | Data set depicts maximum simulated flood depth due to river flooding 10-year return period (10 percent probability of occurring in any given year). Cell values indicate water depth (in m). The threshold used for high hazard is 0.5 m. |

*Source:* World Bank.

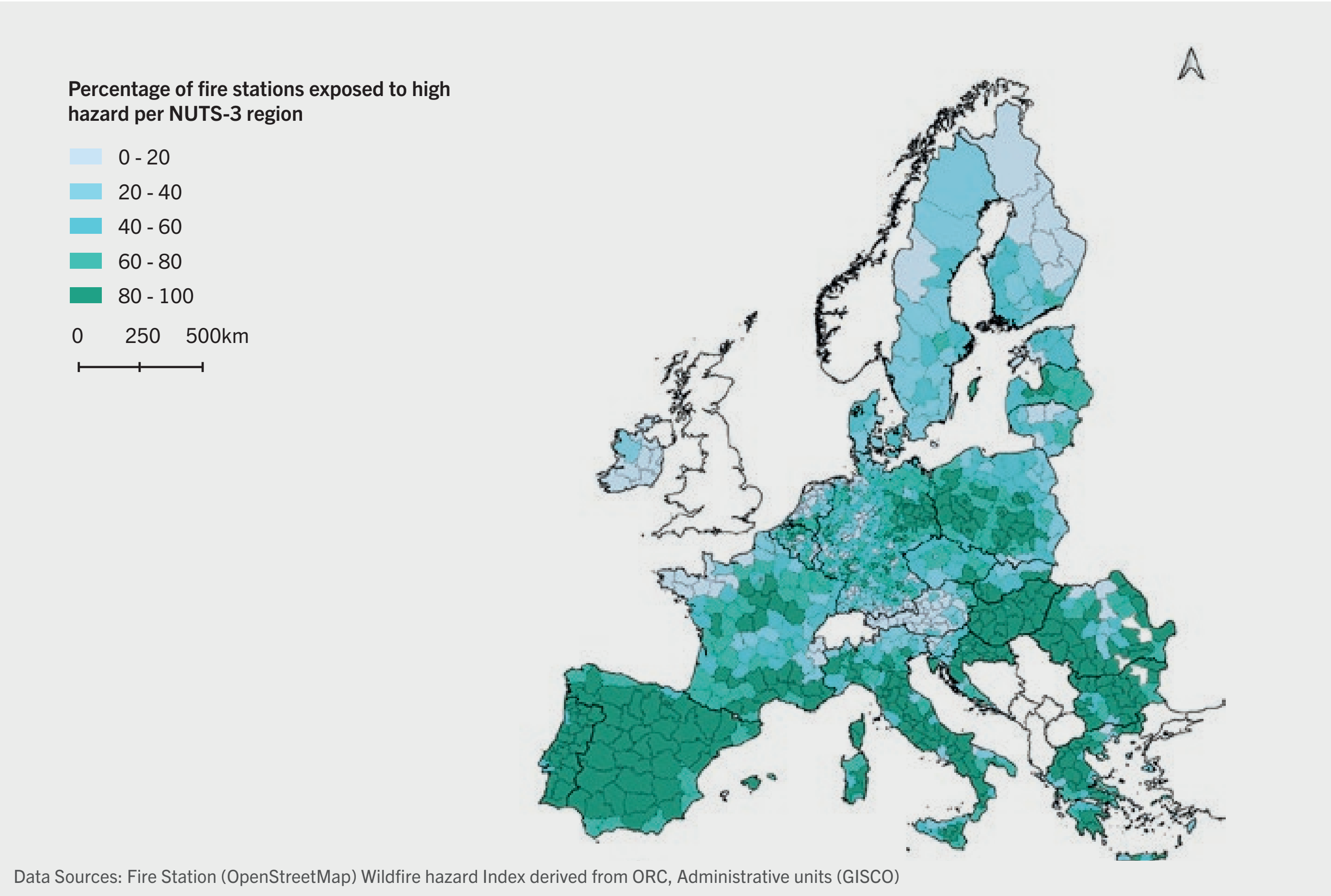
## Outputs

### EXPOSURE TO WILDFIRE

**The results of the exposure analysis show that countries typically associated with high wildfire hazard (for example, Greece, Italy, Portugal, and Spain)** indeed have a high proportion (over 80 percent susceptible to very high wildfire risk) of emergency response-related assets (education, health care, fire, police facilities) exposed to high wildfire hazard. These six EU MSs have 70 percent of their assets exposed to high or very high wildfire risk. The analysis also highlights other countries with high exposure as a proportion of total asset count: also, Bulgaria, Croatia, Cyprus, Hungary, Malta, and Romania all have over 50 percent of their CP assets exposed to high wildfire hazard. This means thousands of assets across Europe are being potentially affected by wildfire. For larger MSs, such as France and Germany, though the share of assets susceptible to wildfire risks seems relatively low in terms of percentage (38 percent for France and 36 percent for Germany), the absolute number of assets being exposed is considerable as well (12,790 for France and 14,752 for Germany).

**EU-wide, the analysis suggests over 52,000 emergency response-related assets (32 percent) are in areas classified in this analysis as high wildfire hazard and 17,000 (10 percent) as very high hazards.** Spatial analysis conducted at the NUTS3 level shows countries in eastern and southern Europe tend to have high exposure across most of their area while in central and northwest Europe exposure may be high in certain NUTS3 units but overall low national exposure.

**Figure 48.** Exposure of fire stations to high wildfire hazard in Europe




*Source:* World Bank.

**An extremely high proportion of roads and power lines are exposed to high and very high wildfire hazards (Table 16).** Six countries have over 90 percent of roads and over 90 percent of power lines exposed: Portugal, Greece, Hungary, Croatia, Cyprus, and Bulgaria. All except four of the analyzed countries have over 50 percent of their road network exposed to high wildfire hazard, and all except four have 40 percent of their power lines network exposed.

**A common trend is that countries with high percentages of roads exposed to high or very high wildfire risks generally also have higher percentages of power lines exposed, such as Greece, Spain, and Hungary.** Exceptions, especially for countries in northern Europe, include Denmark having high percentage (82 percent) of roads exposed, but only 23 percent of power lines in the country face the same level of exposure. Similarly, 75 percent of the roads in the Netherlands are exposed to high wildfire risks, but the percentage drops to 41 percent for power lines in the country. On the other hand, 18 percent of emergency response-related assets are exposed to high wildfire risk. It is crucial to consider the exposure of critical networks to hazards, including wildfires, as they become more frequent and intense. This is particularly important for the EU Critical Entities Resilience Directive 2022/2557, which aims to enhance the resilience of critical entities with EU-wide relevance.[3]

**Table 16.** Length and proportion of road and power line assets exposed to high wildfire hazard per EU MS

| ROADS EXPOSED TO HIGH AND VERY HIGH WILDFIRE HAZARD | | | POWER LINES EXPOSED TO HIGH AND VERY HIGH WILDFIRE HAZARD | | |
|---|---|---|---|---|---|
| **EU MS** | Total km of roads exposed | % Roads | **EU MS** | Total km of power lines exposed | % Power lines |
| **PT** | 4,157 | 100 | **CY** | 788 | 99 |
| **ES** | 13,707 | 99 | **PT** | 13,477 | 98 |
| **EL** | 6,059 | 98 | **HU** | 9,856 | 97 |
| **HU** | 3,574 | 98 | **EL** | 10,703 | 97 |
| **HR** | 2,811 | 97 | **ES** | 49,150 | 94 |
| **IT** | 15,281 | 97 | **HR** | 8,148 | 94 |
| **DE** | 18,424 | 93 | **BG** | 6,633 | 89 |
| **BE** | 3,237 | 90 | **IT** | 53,404 | 86 |
| **BG** | 3,056 | 88 | **RO** | 19,683 | 83 |
| **PL** | 8,056 | 87 | **PL** | 31,834 | 78 |
| **SI** | 929 | 85 | **SK** | 5,357 | 72 |
| **DK** | 1,431 | 82 | **CZ** | 10,692 | 70 |
| **CZ** | 3,188 | 81 | **FR** | 55,675 | 67 |
| **RO** | 5,525 | 81 | **MT** | 8 | 64 |
| **FR** | 20,419 | 80 | **DE** | 39,818 | 64 |
| **SK** | 1,711 | 77 | **BE** | 3,583 | 61 |
| **NL** | 2,397 | 75 | **SE** | 17,005 | 54 |
| **SE** | 7,154 | 72 | **LV** | 2,354 | 47 |
| **AT** | 2,696 | 65 | **SI** | 1,297 | 46 |
| **LV** | 858 | 64 | **NL** | 1,699 | 41 |

3 EU 2022b.

| | | | | | |
|---|---|---|---|---|---|
| LU | 168 | 52 | LU | 237 | 40 |
| EE | 466 | 39 | EE | 2,590 | 36 |
| FI | 2,035 | 38 | AT | 3,429 | 30 |
| LT | 793 | 37 | FI | 6,410 | 30 |
| IE | 455 | 32 | DK | 1,742 | 23 |
| CY | n/a | n/a | IE | 551 | 8 |

*Source:* World Bank.

## EXPOSURE TO FLOODS

**Due to the localized nature of flood hazard, the results of the exposure analysis show that almost 3,500 emergency response-related assets are exposed to flooding of greater than half a meter in a 1-in-10-year river flood event across all MSs.** The countries with greatest exposure as a proportion of assets are Luxembourg (6 percent), the Netherlands (5 percent), Finland (4 percent), and Belgium (4 percent). In the Netherland, 160 of the 235 assets exposed are education facilities. Among the countries with the lowest exposure to flood hazard are those with consistently high exposure to the other analyzed hazards, including Cyprus, Bulgaria, Portugal, and Greece.

**Compared to seismic hazard and wildfire hazard, there is relatively low exposure to high flood hazard, based on this analysis.** This is, in part, due to selecting the basis of this analysis to be the 1-in-10-year river flood hazard and a flood depth of 0.5 m to represent exposure to frequent flooding. Additionally, 1-in-10-year floods would be expected to cause minimal damage in many areas of Europe, due to local standard of flood protection being set to protect against such frequent flooding. However, examining the exposure to frequent flooding does highlight those assets most exposed to recurrent floods, in cases where flood protection is not in place.

**In Slovenia, over 20 percent of power line segments are exposed to high flooding in at least one location along the segment.**[4] Ten more countries have over ten percent of segments exposed to this level of flooding (in decreasing order Croatia (19 percent of all segments in the country], Romania, Latvia, Bulgaria, Slovakia, Austria, Czechia, Sweden, Lithuania, Finland [10 percent]). For context, 64 percent of all segments used in this analysis are bigger than one kilometer in length, while eleven percent are bigger than ten. The majority of the 287,000 segments used reflect a good scale of comparison to the flood hazard data.

**Acknowledging that overhead power lines are likely robust to low levels of flooding, the analysis for power lines considers a higher flood depth threshold than for buildings—2 m instead of 0.5 m—to assess the network segments exposed to high hazard.** This analysis does not provide the *length* of network exposed, due to the form of available data. It does indicate the overall exposure of the power network to flooding in each MS, in that it highlights how much of the network is located in flood-prone areas, reflecting the potential for damage, but does not provide the details of the equipment located in the flood-prone areas, so a detailed assessment of flood effects is not possible.

**In each of Germany, Slovakia, Croatia, and Latvia, over 30 percent of road segments are exposed to high flooding in at least one location along the segment** ('high': at least one point along the segment is exposed to more than half a meter of flood depth at RP10). A further eight countries (Austria, Netherlands, Spain, Hungary, Finland, Czechia, Sweden, and France) have 20–29 percent of segments exposed to this level of flooding. Only Denmark has <10 percent of road segments exposed to this level of flood. For

4 Data are also available for Serbia and North Macedonia, with similar results to Slovenia.

context, 68 percent of all segments used in this analysis are <1 km in length, while 15 percent are more than ten kilometers in length, so the majority of the 15,900 segments used reflect a good scale of comparison to the flood hazard data. This high-level analysis is somewhat sensitive to the length of road segments considered, because road segments of longer length are more likely to include at least one point that is flood prone. When including only segments less than five kilometer in length, the proportion of segments exposed to more than half a meter of flood depth reduces to 18 percent in Germany, 25 percent in Slovakia, 20 percent in Croatia, and 22 percent Latvia. In these types of linear network analysis, examining the spatial distribution of flooding at local scale is important, as is performing network criticality analysis, but these are out of scope for this EU-wide exposure analysis.

### EXPOSURE TO EARTHQUAKE

**The results of the exposure analysis show over 90 percent of emergency response-related assets are in areas that have a ten percent chance in 50 years of experiencing strong seismic shaking** which correlates to buildings sustaining 'light damage' (MMI ≥ VI; 1-in-475-year return period). In Greece, Cyprus, Bulgaria, and Croatia, 90–100 percent of these facilities are exposed to this level of seismic hazard.

**Even in countries with proportionally fewer assets exposed to seismic hazards, such as above 60 percent proportion of exposure in Romania and Italy, as well as or below 40 percent, such as Portugal and Austria, thousands of assets (including over 1,000 educational facilities alone in Greece, Romania, and Italy) are exposed to damaging seismic hazard.** This highlights the importance of seismic strengthening of education facilities in earthquake-prone countries, as education facilities play a crucial role in the local community and the society by housing students and other vulnerable groups, serving educational purposes, and functioning as shelters or resource centers during emergencies.

**In some countries, the seismic exposure for certain types of infrastructure diverges from the overall level of susceptibility for all assets.** For instance, in Italy, though 67 percent of all assets are exposed to high-seismic hazards, the percentage of fire facilities exposed is relatively low (49 percent). Meanwhile, in Slovenia, while overall 79 percent of all assets face high-seismic susceptibility, the exposure level of police facilities is relatively high and reach almost 90 percent.

**The exposure analysis results indicate that, contrary to other hazards, a higher proportion of power lines are in areas that have a ten percent chance in 50 years of experiencing strong seismic shaking (MMI** ≥ Table 17). In Slovenia, Greece, Bulgaria, and Croatia, more than 90 percent of roads are exposed to this level of seismic hazard. Similarly, over 90 percent of power lines in each of Greece, Cyprus, Slovenia, Bulgaria, and Croatia are exposed.

**Similar trends in terms of exposure are shown for seismic risk exposure of roads and power lines.** For instance, for all countries with a high percentage of roads (90 percent and above) exposed, the percentage of power lines exposed to seismic risk is also ranked high (except Cyprus where no data are available for road exposure). On the other hand, countries with few or zero roads exposed to seismic risk also have low levels of seismic exposure for power lines. One exception to this trend is Hungary where 26 percent of roads in the country are exposed to MMI ≥ VI shaking—only eight percent of the power lines show the same level of seismic exposure.

**Also, for both roads and power lines, countries in Europe have either high (70 percent and above) or low (35 percent and below) proportions exposed to VI and above seismic susceptibility.** Almost no country has a medium percentage (35–70 percent) of roads or power lines exposed to seismic risk. This reflects that it is crucial for countries with high-seismic susceptibility to be prepared, as a majority of their roads and power lines will be affected and lead to huge damage and loss if a seismic event occurs.

**Table 17.** Number and proportion of road and power line assets exposed to high-seismic intensity (MMI ≥ VI) per EU MS

| ROADS EXPOSED TO SEISMIC SHAKING INTENSITY MMI ≥ VI | | | POWER LINES EXPOSED TO SEISMIC SHAKING INTENSITY MMI ≥ VI | | |
|---|---|---|---|---|---|
| **EU MS** | Total km of road exposed | % Roads | **EU MS** | Total km of power lines exposed | % Power lines |
| **SI** | 1,095 | 100 | **EL** | 11,088 | 100 |
| **EL** | 6,183 | 100 | **CY** | 795 | 100 |
| **BG** | 3,331 | 96 | **SI** | 2,730 | 98 |
| **HR** | 2,625 | 91 | **BG** | 7,269 | 97 |
| **IT** | 13,742 | 87 | **HR** | 8,061 | 93 |
| **RO** | 4,811 | 70 | **IT** | 48,222 | 78 |
| **AT** | 1,751 | 42 | **RO** | 17,739 | 75 |
| **PT** | 1,497 | 36 | **PT** | 4,836 | 35 |
| **ES** | 4,188 | 30 | **AT** | 3,217 | 28 |
| **HU** | 964 | 26 | **ES** | 9,112 | 17 |
| **DE** | 1,342 | 7 | **HU** | 789 | 8 |
| **BE** | 220 | 6 | **FR** | 3,038 | 4 |
| **FR** | 1,216 | 5 | **DE** | 1,770 | 3 |
| **NL** | 54 | 2 | **SK** | 102 | 1 |
| **CZ** | n.a. | 0 | **CZ** | 26 | 0 |

*Source:* World Bank.

## EXPOSURE TO LANDSLIDES

**The results of the exposure analysis show that, compared to seismic hazard and wildfire hazard, there is relatively low exposure to high landslide susceptibility.** The maximum exposure is 21 percent of all assets, in Italy. Only five EU MSs have over ten percent of emergency response-related assets exposed, and this is likely to be because landslide susceptibility is highly influenced by slope, and few such buildings are built in areas of steep slopes. However, to fully address the risk to assets in areas of high susceptibility, more detailed landslide run-out modeling would be required.

**Eleven countries have hundreds of assets in areas of high landslide susceptibility, and several have thousands of assets exposed—namely Italy, Austria, France, and Germany**. Even in France where only seven percent of all assets are in areas of high and very high landslide susceptibility, this translates to thousands of schools and hundreds of health care, fire, and police facilities. The asset type most exposed to landslide varies. For example, in Italy 21 percent of emergency response-related assets is exposed, but fire stations have a proportionally higher exposure (36 percent) than police (21 percent), education (19 percent), or health care (19 percent). In Slovenia, however, 18 percent of emergency response-related assets is exposed, and education buildings have the highest exposure proportionally (25 percent) compared to police (13 percent), fire (18 percent), or health care (10 percent), demonstrating the need to understand and respond to sectoral differences exposure from country to country.

**This analysis indicates the number of assets that are in an area of high susceptibility, based on an EU-wide assessment.** It does not consider property-level engineering, slope stabilization, and modifications, which may limit the occurrence of landslides and impact on the assets themselves.

**According to the exposure analysis results, a greater percentage of roads are at risk of high and very high landslide susceptibility compared to power lines.** Specifically, in Spain, Ireland, Slovenia, Portugal, Austria, and Greece, more than 80 percent of roads are in areas of high and very high landslide susceptibility. On the other hand, in Greece, Slovenia, Spain, and Bulgaria, 70 percent or more of power lines are in areas of high and very high landslide susceptibility. These figures are highly influenced by the length of network segments because the analysis measures the maximum and mean per segment, without segmenting the network further than provided in the data.

**In several countries, the length of road network exposed is over 12,000 km including in Spain, Italy, France, and Germany**. In Italy and Spain over 40,000 km of power lines are exposed.

## TABLES

**Summary tables have been produced to show, for each MS, the number and percentage of one asset type falling into the defined hazard classes and the total number of assets exposed to the hazard.** An example of this table is given in Table 18.

**Table 18.** Extract from data table showing police stations exposed to wildfire in each EU MS

| | NUMBER OF EXPOSED ASSETS (BY HAZARD LEVEL AND TOTAL) | | | | | | |
|---|---|---|---|---|---|---|---|
| EU MS | WF1 | WF2 | WF3 | WF4 | WF5 | Total assets exposed | Total assets |
| ES | 174 | 63 | 233 | 1,041 | 1,452 | 2,963 | 3,212 |
| IT | 494 | 482 | 664 | 2,021 | 1,297 | 4,958 | 5,415 |
| FR | 714 | 1,485 | 863 | 1,589 | 626 | 5,277 | 5,476 |
| PT | 89 | 0 | 6 | 141 | 545 | 781 | 903 |
| EL | 49 | 6 | 13 | 83 | 143 | 294 | 385 |
| DE | 333 | 1,277 | 616 | 1,301 | 99 | 3,626 | 3,685 |
| PL | 55 | 373 | 345 | 879 | 92 | 1,744 | 1,768 |
| HR | 10 | 15 | 9 | 127 | 54 | 215 | 238 |
| HU | 31 | 7 | 78 | 384 | 48 | 548 | 551 |
| CY | 3 | 0 | 1 | 13 | 39 | 56 | 68 |

*Source:* World Bank.
*Note:* Only top ten rows are shown. Full tables are available.

| | PERCENTAGE OF EXPOSED ASSETS (BY HAZARD LEVEL AND TOTAL) | | | | | |
|---|---|---|---|---|---|---|
| **EU MS** | **WF1** | **WF2** | **WF3** | **WF4** | **WF5** | **Total assets exposed** |
| **ES** | 5 | 2 | 7 | 32 | 45 | 92 |
| **IT** | 9 | 9 | 12 | 37 | 24 | 92 |
| **FR** | 13 | 27 | 16 | 29 | 11 | 96 |
| **PT** | 10 | 0 | 1 | 16 | 60 | 86 |
| **EL** | 13 | 2 | 3 | 22 | 37 | 76 |
| **DE** | 9 | 35 | 17 | 35 | 3 | 98 |
| **PL** | 3 | 21 | 20 | 50 | 5 | 99 |
| **HR** | 4 | 6 | 4 | 53 | 23 | 90 |
| **HU** | 6 | 1 | 14 | 70 | 9 | 99 |
| **CY** | 4 | 0 | 1 | 19 | 57 | 82 |

*Source:* World Bank.
*Note:* Only top ten rows are shown. Full tables are available.

## MAPS

**Selected maps are shown in this report and all maps are compiled in a supplementary PDF map book.** Three different types of maps were produced under this report to visualize the results to allow for broader purposes. The maps were also prepared at different scales, including maps at the EU level as well as granular maps for case study countries Croatia, Romania, and Portugal.

1. *NUTS3 choropleth maps* at the EU-wide scale for each hazard, produced for an all-MS view and EU-wide identification of hotspots,
2. *Dot maps* at the country level showing the location of assets as well as level of hazard per asset, overlaid on the original hazard data layer,
3. *Circle maps* at the country level showing the number of assets exposed to high hazard per NUTS3, with distribution of hazard across the country.

**These maps are an invaluable tool for assessing exposure to hazards from multiple perspectives, making them an essential aid for decision-making**. One of the key benefits of these maps is their versatility, as they can serve a variety of purposes depending on the user's needs.

# ANNEX 2: Complementary Information relevant to Prioritized Investments

This Annex provides additional, complementary information to prioritized investments as outlined in Chapter 2 and includes a reminder about the types of DRM investments, key considerations when developing prioritization frameworks, additional prioritization tools, a sample roadmap, and fictional case to illustrate the prioritization process.

## TYPES OF DRM INVESTMENTS

**There are different types of DRM investments, and they span across different phases of the DRM cycle.**[5] DRM investments can relate to risk identification (risk assessments and so on), risk reduction (such as upgrading critical sectors or constructing risk mitigation measures), prevention, early warning, emergency preparedness and response, public awareness, and financial resilience (various instruments), and DRM investments can be prepared and implemented by different stakeholders, including national and subnational actors, the private sector, communities, and even regional and global organizations. DRM investments can target a single or ideally multiple hazards, and they can be holistic in nature, seeking to consider all aspects of a system/situation or have a specific sectoral or narrow focus.[6] Commonly, DRM investments are also divided between structural (engineered) and nonstructural, but there also are hybrid, NBSs and several other typologies. Each type of DRM investment has its own benefits, limitations, and price tag, and the most effective approach depends on the context and risks faced by a community, country, or group of countries—more information in Box 18.

**BOX 18.** TYPES OF DRM INVESTMENTS

**Single versus multi-hazard.** DRM investments can have a single- or multi-hazard focus and consequently differ in their scope and objectives. A single-hazard focus addresses a specific type of hazard such as floods, earthquakes, or wildfires, and the intervention is typically tailored to the characteristics of that hazard. Multi-hazard investments, on the other hand, address multiple hazards that may affect a community, country, or region. The choice between single- and multi-hazard interventions depends on several factors including context, available resources, and priorities. The multi-hazard approach is preferable and recognizes that disasters may have cascading effects, as seen in the Tohoku earthquake in 2011 in Japan which caused a tsunami which in turn caused a nuclear fallout. Another example is the 2010 eruption of Eyjafjallajökull volcano in Iceland which led to a significant disruption in air travel and had cascading effects on various economic sectors across multiple countries.

**Structural versus nonstructural.** Structural investments usually include the construction of physical infrastructure and can be further subdivided into so-called grey, green, or blue infrastructure. Grey infrastructure includes typically engineering solutions such as fixed or mobile flood barriers like dams or sea walls, whereas green infrastructure (GI) comprises NBS/ecosystem-based solutions such as reforestation or green roofing.[7] Blue infrastructure refers to water-related solutions like rivers, canals, ponds, wetlands, floodplains, water treatment facilities, and storm water provisions. Nonstructural investments, on the other hand, are knowledge or concept based and cover measures like capacity building, education, and training; risk transfer

5 Poljanšek et al. 2017. *Science for Disaster Risk Management 2017: Knowing Better and Losing Less.* Ispra, Italy: JRC. Link; IPCC. 2012a. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Cambridge* University Press: New York, United States. Link.
6 UNDRR. 2019. Developing National Disaster Risk Reduction Strategies. Geneva, Switzerland: UNDRR. Words into Action No. 4. Link.
7 World Bank/GFDRR 2023.

mechanisms such as insurance and social safety nets; emergency response and contingency planning[8] frameworks; and so on. In practice, a combination of structural and nonstructural measures should be selected in a balanced and complementary manner.

**Sectoral versus holistic.** Sectoral investments may focus on mainstreaming DRM into transport, agriculture and forestry, health, and other sectors, aiming to reduce vulnerability and/or increase resilience of that specific sector. Other investments may focus on the overall DRM strategy of a country and aim to improve systemic resilience that is relevant across multiple hazards—such as assessment of risks, early warning systems, or general emergency response capacities. DRM investments may be related to different phases or 'pillars' of DRM: (a) risk identification and quantification, (b) risk reduction, (c) preparedness, (d) financial protection, and (e) resilient recovery and reconstruction.[9] Both types are important, complementing each other and together ensuring a more comprehensive or integrated approach.

**An illustrative overview of possible DRM investments grouped by the natural hazards and its main objective/purpose is included in Table 19.** Typical types of investments include risk analytics and profiling, strategic policy decision and action plans, development and enforcement of building codes and standards (appropriate zoning and so on), green and grey infrastructure approaches, crowding in of the private sector and local prevention actions, and so on. The choice of investment type depends on the specific context, available resources, and priorities.

**Table 19.** Example DRM investments by natural hazards and objectives

| RISK | ANALYTICS AND POLICIES | INFRASTRUCTURE AND EQUIPMENT | HUMAN CAPITAL AND SOCIAL ASPECTS | ENVIRONMENT AND SUSTAINABILITY |
|---|---|---|---|---|
| **Multi-hazard** | Multi-hazard risk assessments, scenario planning, emergency response plans, response time analytics enhanced by GIS/real-time monitoring<br>Early warning, connectivity, and interoperability of alert systems and so on.<br>Social inclusion and adaptive social protection systems | CP and emergency response assets and equipment (for example, sensors or gauges for monitoring)<br>Critical sectors' assets and equipment necessary for emergency response<br>Retrofitting of infrastructure with a multi-hazard view | Professional staff and volunteer training<br>Drills and exercises to enhance coordination and preparedness<br>Community outreach and awareness raising, including, for example, at schools<br>First-aid training, demonstrations, and so on | Greening efforts of CP and emergency response sector (or other critical sectors)<br>Restoration and preservation of natural ecosystems that can act as a buffer against multiple hazards |

8 A management process that analyzes disaster risks and establishes arrangements in advance to enable timely, effective, and appropriate responses. (UNDRR. 2023b. *Sendai Framework Terminology on Disaster Risk Reduction*. Link)

9 GFDRR. 2014. *Understanding Risk in an Evolving World - Emerging Best Practices in Natural hazard Risk Assessment*. Link.

| RISK | ANALYTICS AND POLICIES | INFRASTRUCTURE AND EQUIPMENT | HUMAN CAPITAL AND SOCIAL ASPECTS | ENVIRONMENT AND SUSTAINABILITY |
|---|---|---|---|---|
| **Wildfire** | Wildfire risk analytics for current and future projections<br>Advanced technologies (satellite monitoring for early warning)<br>Established mutual aid agreements for coordinated response<br>Land use planning and zoning policies, especially related to WUI<br>Risk transfer policies | Physical barriers, such as firebreaks, to prevent the spread of wildfires and protect communities<br>Specific design/ protection of high-risk facilities (fuel depots and so on)<br>Firefighting equipment | Training programs for firefighters<br>Community drills to promote fire safe practices and evacuation plans<br>Public awareness campaigns on how to avoid wildfires | Vegetation management through controlled burns, defensible space creation, and forest thinning to reduce fuel for wildfires<br>Restoration of ecosystems and biodiversity (for example, reforestation and drought/heat management programs) |
| **Floods** | Flood risk analytics for current and future projections<br>Floodplain mapping, land use planning, and zoning regulations to restrict development in flood-prone areas<br>Regular inspection, maintenance, and reinforcement of levees and dams to prevent failures | Stormwater management infrastructure to control runoff and reduce the risk of flash floods<br>Flood protection system combining different measures<br>Advanced flood monitoring and early warning systems to provide timely alerts to at-risk communities | Community-based programs that educate residents about flood risks, evacuation plans, and emergency response procedures | NBS such as restoration of wetlands and natural floodplains, which can act as natural buffers against flooding<br>Green measures at the urban scale—'sponge cities', improved drainage and retention capacities, or planning of multi-purpose areas |
| **Earthquake** | Seismic zoning regulations and building codes to ensure new constructions are earthquake resistant<br>Policies to enhance collaboration with civil society groups, for example, to enhance self-preparedness and response, for example, among vulnerable groups<br>Adaptive social protection programs | Investment in infrastructure resilience (retrofitting or rehabilitation) to withstand seismic events and reduce vulnerability<br>Seismic monitoring networks | Training to first responders, emergency services, and volunteers on search and rescue techniques, medical triage, and coordination protocols<br>Public campaigns to raise awareness about earthquake preparedness, evacuation routes, and response procedures | Planning of multi-purpose evacuation places<br>Integrated solutions combining seismic resilience with energy efficiency and/or climate change-related designs elements—tackling also urban heat island (UHI) effect and so on |

| RISK | ANALYTICS AND POLICIES | INFRASTRUCTURE AND EQUIPMENT | HUMAN CAPITAL AND SOCIAL ASPECTS | ENVIRONMENT AND SUSTAINABILITY |
|---|---|---|---|---|
| **Landslide** | Zoning regulations and land use planning to restrict deforestation and construction in vulnerable areas and guide sustainable development | Engineered/green solutions to stabilize slopes, reinforce vulnerable terrain, and install protective structures to mitigate landslide risks | Community training programs to educate residents about recognizing warning signs and taking appropriate actions during landslide events | (Re)forestation programs to increase vegetation cover in landslide-prone areas |

**Some DRM investment are also called no-regret, low-regret, and win-win options which are rooted in the acknowledgment of uncertainty.** No-regret options comprise the strategic selection of measures that provide benefits under various future scenarios, even in the absence of complete information or certainty about the nature and magnitude of future risks. They offer positive benefits even in the absence of perfect foresight. Early warning systems, for instance, are considered a no-regret investment because of their multiple benefits in view of preparedness and response, and their scalability and flexibility make them applicable across a range of scenarios and hazards. Besides no-regret options, depending on the context, there are low-regret options which describe a varying degree of positive net benefits. They are not universally beneficial in all circumstances but still offer positive outcomes in many/most scenarios. Lastly, win-win options in the context of DRM investment frameworks refer to strategies that not only enhance resilience to disasters but also contribute to other broader development goals. They are characterized by an integrated, comprehensive, and sustainable approach.

**Understanding the link between DRM investments and cost of inaction is crucial for decision-makers to evaluate the benefits of investing in DRM measures compared to the potential losses incurred if no action is taken.** By assessing the economic, social, and environmental consequences of inaction, decision-makers can justify and prioritize investments in DRM measures that offer positive returns in terms of risk reduction, improved resilience, and overall societal well-being.

**When implementing DRM investments in one region or country, there is a potential for both positive and negative spillover effects that can affect neighboring areas or even have broader international ramifications.** DRM investments in one region may either inadvertently shift risks or vulnerabilities to neighboring areas or indirectly benefit neighboring areas or countries in terms of reduced risks. To address these spillover effects, it is crucial to adopt a collaborative and integrated approach to DRM. Cooperation among neighboring regions or countries is essential to ensure that investments are coordinated, and potential negative spillover effects are minimized. This requires effective communication, information sharing, and joint decision-making processes to align priorities and address shared risks. Multi-country/international frameworks and agreements can play a vital role in managing spillover effects, facilitate coordinated investments, and address cross-border risks.

## KEY ELEMENTS OR "BUILDING BLOCKS" OF PRIORITIZATION FRAMEWORKS

### Governance-related aspects

**Global/other frameworks provide general guidance to establishing strategies priorities.** The SFDRR, for instance, provides a global framework with seven targets, four strategic priorities, and eleven guiding principles and is intrinsically linked to the 2030 Agenda and the planning process thereunder. The SFDRR also contributes and is linked to several goals of the United Nation's 2030 Agenda for Sustainable Development.[10] This framework is commonly used by

10 See further details about the 2030 Agenda at UN. *Transforming Our World: The 2030 Agenda for Sustainable Development.* Link.

countries to provide a structure for national strategies, which in turn guide subnational strategies. For example, the Romanian draft National Disaster Risk Reduction Strategy, which is being finalized by the authorities, closely follows the principles and priorities of the SFDRR while also contributing to the achievement of the SDGs. Noteworthy sectoral guidelines/frameworks to help scale up resilient infrastructure are the United Nations Office for Disaster Risk Reduction (UNDRR) 'Principles for Resilient Infrastructure'[11] and the World Bank/Global Facility for Disaster Reduction and Recovery (GFDRR)'s 'Lifelines-The Resilient Infrastructure Opportunity'[12] reports.

**At the EU level, the SFDRR and SDG agenda are further complemented by the EU's Action Plan on Climate as well as DRGs' five strategic areas for CP which are expected to inform the priorities of the EU MSs in the coming years.** The goals set at the EU level provide a common direction for MSs to align their efforts and prioritize their actions. They foster a common understanding of the importance of disaster resilience and provide a platform for sharing best practices, exchanging knowledge, and promoting mutual learning among countries.

**Priorities at the EU level are then replicated through national DRM plans or strategies which guide national efforts in identifying, assessing, and managing risks associated with prevailing hazards.** National plans and strategies outline key visions/objectives, key disaster/climate risks, challenges and gaps, priorities and expected outcomes, and implementation plans and arrangements. The plans/strategies help ensure that DRM efforts are structured, proactive, and tailored to the specific risks at the national level and provide guidance for actions at other levels, among other stakeholders.

**Once strategic priorities have been identified, they are then reflected in national budget allocations and operationalized through dedicated programs.** These can be comprehensive flagship programs or mainstreamed across economic development efforts. Greece, for instance, adopted the national Aegis program to upgrade and reform its CP sector,[13] and in the Netherlands, the government funds the Delta Works Program for flood risk reduction with structural and nonstructural measures as well as NBSs to prevent the reoccurrence of major disasters like the ones in 1953 and early 1990s.[14]

### Disaster and climate-related aspects

**Decisions on DRM investments are generally grounded in an understanding of hazards, exposure, vulnerability, impact, and risk, but several methodologies and approaches can be considered.** Risk-based approaches consider the elements and interaction of elements of risk—hazard, vulnerability, and exposure. Prioritization across multiple hazards requires a deep understanding of risks being considered and their interrelationships/interdependencies. When appropriate, cascading effects are also considered.

**To better understand possible outcomes and their associated probabilities, probabilistic modeling is a used in situations where uncertainty and variability play a significant role.** It is a robust mathematical and statistical approach to quantify and analyze various outcomes and their probabilities in complex systems or situations and used to enable better risk management and strategic planning. In DRM, probabilistic modeling can be applied to assess the likelihood of various hazards occurring, their potential impacts, and the resulting risks. This approach provides decision-makers with a more comprehensive understanding of the range of possible scenarios and helps guide more informed choices.

11 UNDRR. 2022. *Principles for Resilient Infrastructure.* Geneva, Switzerland: UNDRR. Link.
12 Hallegatte, Rentschler, and Rozenberg 2019.
13 'Aegis', the largest program ever designed to strengthen CP in Greece. The total budget of the project is €1.7 billion, of which €380 million comes from the Recovery Fund. Defence Exhibition Athens. 2022. *Civil Protection: Tenders 1.7 Billion for Helicopters, Firefighting Aircraft, Drones.* Link.
14 Government of the Netherlands. 2023. D*elta Programme: Flood Safety, Freshwater and Spatial Adaptation.* Link.

**Risk prioritization indexes may be defined, employing a weighted summation of multiple considered attributes** (for example, probability, impact, proximity, spatial context, uncertainty, manageability, and response effectiveness).[15] Weights should be clearly established to enhance transparency. Expert opinion is normally incorporated into the prioritization process.[16] At the EU level, risk information is, for example, available through the Index for Risk Management (INFORM), developed by the JRC, and this can be used to set priorities for risk management, preparedness, and resilience building; support decisions on resource allocation; and track risk trends over time.[17]

**Risk-based approaches are commonly used to evaluate and compare individual investment options.** Key advantages are the easy-to-understand and easy-to-communicate results,[18] the adaptability to different contexts and hazards, and the ability to take decisions based on solid evidence which enhances objectivity of the framework. The weaknesses of this approach are that risks are generally subject to uncertainty and incomplete or unreliable data can affect the overall reliability of results. Furthermore, risks are not static but can evolve over time due to various factors such as environmental changes, socioeconomic developments, technological advancements, and shifts in population patterns.[19] By focusing too much on the risks, there is also a chance that the perspectives and needs of local communities may be neglected.

**In practice, risk-based approaches may feed into more complex approaches (such as MCA) or are used to assess the likelihood of infrastructure failure or disruption (individual elements or whole system) due to natural or man-made hazards and the socioeconomic consequences of such failure/disruption.** It can be applied on a portfolio of assets (for example, from Romania) or on various networks (criticality analysis).[20] The approach is generally highly data driven and can include statistics, geographic information, satellite imagery, weather forecasts, artificial intelligence, and other innovative sources. Sound and reliable analytics identify patterns, trends, and risks which in turn enable the effective comparison and prioritization of available investment options.

**Prioritization of interventions in DRM must consider evolving risks with climate change, including average changes and likelihood of increasingly disruptive events.** This is generally based on projections of temperature and precipitation change, ideally based on downscaled models to make projections at finer temporal and spatial scales. This must be accompanied by knowledge of disaster risks and—when available—projections of changing return periods of these events or storylines of probable extreme events. Ideally, this should consider a wealth of socioeconomic and climate scenarios and a number of different possible extreme events. The combination of these can help reduce the risk of maladaptation given high variability of possible impacts as a result of climate change. Increasingly, time horizons for planning and decision criteria are aligning between DRM and CCA. However, CCA interventions still require looking further into the future to gauge whether the interventions would still provide benefits. Ultimately, as in the DRM space, decisions about CCA measures to prioritize and implement must be grounded in sociopolitical systems and require societal rather than solely technical prioritization, as they must consider trade-offs and acceptable potential levels of risks and losses.[21]

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15 Poljanšek et al. 2017; IPCC 2012.

16 Ioannou et al. 2022. "Prioritization of Hazards for Risk and Resilience Management through Elicitation of Expert Judgement." Natural Hazards 112: 2773–2795. Link.

17 For more information about the INFORM index, see JRC. DRMKC - INFORM. Link.

18 For example, the risk communication tool RiskViewer for Latin America and the Caribbean. World Bank/GFDRR. LAC RiskViewer. Link.

19 Cremen et al. 2022. "Modelling and Quantifying Tomorrow's Risks from Natural Hazards." *Science of the Total Environment* 817. Link.

20 For further information about multisectoral and multi-hazard infrastructure network risk analysis, see Mahul et al. 2021. *Piloting the Next Generation Analytics for Climate-Related Financial Resilience of Critical Infrastructure in Southeast Asia.* Link.

21 The Economics for Disaster Prevention and Preparedness (EDPP) 2 Component 2 report provides further information on CCA costing.

### Financial/economic, social, and environmental aspects

**When prioritizing DRM investments, financial and economic aspects naturally play a crucial role.** These aspects involve the consideration of financial resources and allocation, funding mechanisms and leveraging of additional resources, cost-effectiveness in decision-making, and financial/economic sustainability. Several methodologies are used for financial/economic analysis of DRR investments.[22] These may include the following: the TDR framework, BCA, RoR, RoI, and CEA. An example of a framework which considers different financial and economic elements is included in Box 4.

**BOX 19.** DEVELOPING A BUSINESS CASE FOR INVESTMENTS IN THE UNITED KINGDOM

The United Kingdom's Treasury provides guidance on how to conceptualize projects and business cases through a Five Case Model Methodology. This methodology comprises five key considerations: (a) the strategic case determines the need for change, its strategic fit, and rationale for intervention; (b) the economic case looks at the net value to society compared to continuing with business as usual; (c) the commercial case determines a well-structured 'ideal' between the public sector and its service providers; (d) the financial case demonstrates the affordability and funding of the preferred option; and (e) the management case ensures that viable arrangements are in place for the delivery, monitoring, and evaluation of bespoke project or investment.[23] This methodology is applicable to policies, strategies, and projects and investment programs.

**By considering environmental aspects, decision-makers can integrate environmental considerations into risk reduction measures, ensuring a holistic and sustainable approach to DRM.** For example, one can prioritize DRM investments that promote environmental sustainability, protect ecosystems, manage natural resources, and minimize environmental risks.

**Social aspects involve understanding and addressing the social dimensions, impacts, and considerations associated with DRM interventions.** Decision-makers can prioritize DRM investments that address social vulnerabilities, promote community engagement and resilience, ensure gender inclusivity, and respect cultural values. Furthermore, this approach can contribute to fostering wider social equity, empowering citizens and communities, and ensuring more sustainable and people-centered DRM initiatives. These aspects are generally difficult to quantify. Behavioral and cultural aspects involve understanding how individuals and communities perceive, respond to, and adapt to disaster risks and incorporating these aspects in decision-making to develop more culturally sensitive, contextually appropriate, and effective DRM interventions.

### Other elements

**Depending on the context, other elements may be relevant as well, for instance, sectoral or cross-sectoral issues, knowledge or information management, or technology and innovation aspects.** Table 20 presents five key trade-offs that can prevent implementation if not addressed: power relations and inclusion aspects; issues around equity, needs, and benefits of different stakeholder groups; temporal trade-offs in terms of short-term gains versus long-term costs (for example, carbon emissions); mitigation of one risk which may exacerbate another; and maximizing of development gains while accounting for disaster risk and uncertainty.[24] Their applicability can vary depending on the local context and needs.

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22 World Bank and European Commission 2021a, 36.

23 UK HM Treasury. 2018. "Guide to Developing the Project Business Case - Better Business Cases: for Better Outcomes." London: Open Government License (OGL). Link.

24 SEI (Stockholm Environment Institute). 2017. *How Do We Prioritize When Making Decisions about Development and Disaster Risk? A Look at Five Key Trade-Offs.* Discussion Brief. Bangkok, Thailand: SEI. Link.

**Table 20.** Key trade-offs in development and DRR decision-making

| | |
|---|---|
| **Power** | • Who is and is not involved in the decision-making process? Which criteria are used to select actors for involvement? What is the appropriate level and extent of involvement? How are elite capture and marginalization avoided?<br>• Who decides the agenda and goals of the process? Is it tied to funding?<br>• How are decision-makers held accountable?<br>• What are the costs and resources necessary for inclusion? |
| **Equity** | • How is equity defined in practice?<br>• Who benefits and who is harmed by a given decision? Are the potential losers involved in the decision-making process?<br>• How can vulnerable and marginalized people be included in the process?<br>• Have indirect impacts of decisions been identified and addressed in the decision-making process?<br>• What are the resources needed to analyze impacts? |
| **Temporal** | • What is the appropriate time frame for which risks, costs, and benefits should be considered?<br>• What is the appropriate case-specific discount rate, and how does the discount rate affect the outcome of decision?<br>• What are the long-term impacts of decisions?<br>• How are decision-makers held accountable for the long-term impacts of their choices? |
| **Risk** | • What are the content, uncertainties, and known and unknown risks related to the decision?<br>• How are risks prioritized by those needing to act to decrease disaster risk?<br>• What assumptions are made in technical assessment of risks? Do they reflect how actual people assess risks in their own lives?<br>• What level of collaborative learning with stakeholders is optimal? What resources are needed for it? |
| **Aggregation** | • How are the losses measured, and what are they measured in relation to?<br>• What key indicators need to be measured alongside gross domestic product (GDP) for a balanced view of sustainable development and DRR?<br>• To what extent are social, environmental, and economic aspects integrated?<br>• To what extent are indirect impacts (social, environmental, and economic) considered? |

*Source:* SEI 2017.

## KEY CONSIDERATION OF PRIORITIZATION FRAMEWORKS

In the below box, the reader can find a checklist of key considerations useful for developing a prioritization framework.

**BOX 20.** CHECKLIST WITH KEY CONSIDERATIONS

**Governance/strategy-related aspects**

- *Considering* strategies, plans, policies, regulations, institutional systems that shape DRM as well as broader development strategies and interventions, and specific objectives/goals.[25]
- *Considerations of existing investments, measures, capacities in broader sense, and potential gaps*, for example, through a review of past, ongoing, and planned investments.
- *Possible positive and negative spillover effects of DRM investments* that can affect neighboring areas or even have broader international ramifications should be addressed in a collaborative, integrated, and internationally coordinated approach.

**Disaster and climate risk aspects**[26]

- *Prevalence of natural and man-made hazards which assesses the frequency or occurrence of events that pose risks to population, economy*, or infrastructure.
- *Historical information about impacts* which provide valuable insights into the past occurrences and consequences of disasters which can be used for assessing risks, identifying high-risk areas, understanding vulnerability and exposure, and assessing effectiveness of past interventions.
- *Existence of cascading risks* which evaluates the potential of existing hazards triggering a chain of events or secondary hazards.
- *Public perceptions about prevalent risks* which influence the effectiveness, acceptance, and sustainability of implemented measures.
- *Projections about future trends and uncertainties* which seek to anticipate potential changes in the risk landscape and in terms of vulnerability and exposure and to ensure sustainability from CCA and mitigation perspectives. Future projections enable scenario planning and assessing of robustness of interventions under different conditions.

**Financial/economic, social, and environmental aspects**

- *Financial costs and funding pathways*. Ensure that DRM investments are financially feasible, economically sustainable, and aligned with available resources. Involve the optimization of allocations, exploration of innovative financing mechanisms, and prioritization of investments that provide the best cost-effectiveness and long-term benefits.
- *Social, environmental risks, impacts, and benefits*. Risks and potential impacts and socioeconomic sustainability need to be considered along with potential benefits/co-benefits that offer multiple advantages that go beyond DRR and can create more holistic and sustainable solutions that benefit both communities and the environment.[27]
- *Behavioral and cultural aspects and involving vulnerable communities*. Understanding how individuals and communities perceive, respond to, and adapt to disaster risks and incorporating these aspects in decision-making to develop more culturally sensitive, contextually appropriate, and effective DRM interventions.

**Other context-specific considerations**

- A specific focus on a sector, a geographic area, and fragile situations may reveal additional context-specific considerations, including in lagging regions, capacity-related aspects, areas with more isolated or marginalized communities, or even areas with the most likely success to build on.

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25 Albris et al. 2020. "Strengthening Governance for Disaster Prevention: The Enhancing Risk Management Capabilities Guidelines." *International Journal of Disaster Risk Reduction* 47. Link.

26 Government of Australia, Department of Home Affairs. 2019. C*limate and Disaster Risk: What They Are, Why They Matter and How to Consider Them in Decision Making. 5 Guidance on Prioritization*. Link.

27 Vorhies, F., and E. Wilkinson. 2016. "The Triple Dividend of Resilience - Co-Benefits of Disaster Risk Management." World Bank Policy Research Working Paper No. 7633. Link.

## ADDITIONAL PRIORITIZATION TOOLS

**In addition to the prioritization tools discussed in the main report, other prioritization may also be considered**. The below approaches may be utilized in combination with other prioritization tools, depending on data availability, resources, and needs.

### Scenario-based approach

**A scenario-based approach involves developing and analyzing specific disaster scenarios and assessing the effectiveness of relevant DRM investments in reducing the impacts of bespoke scenarios.** The objective is to identify the most effective and efficient DRM measures for each scenario and allocate resources accordingly. The advantage of the scenario-based approach is that it enables decision-makers to identify and prioritize the most effective DRM measures for specific disaster scenarios and allocate resources more efficiently to maximize the impact of DRM investments.[28]

**Scenario analysis is a specifically valuable tool for emergency response planning and preparedness** because it helps emergency response teams anticipate and prepare for various potential situations and their associated challenges. For instance, it allows teams to navigate the challenges posed by different scenarios, thereby improving the overall efficiency and resource optimization as well as effectiveness of the overall response efforts.[29] For prevention, scenario analysis can also play a vital role as it helps stakeholders understand potential risks and develop strategies to mitigate them. Well-defined scenarios can help identify and address potential risks, enhance preparedness, and implement targeted interventions to reduce the impact of disasters on communities, infrastructure, and the environment.

### Decision-making under deep uncertainty

**Decision-making under deep uncertainty is a broad concept and involves a comprehensive approach in contexts with great uncertainty that is difficult to quantify.** It enables decision-makers to look beyond the individual infrastructure investment and take into account broader user and welfare perspectives with potentially large impacts. The types of uncertainties include model uncertainty, data uncertainty, scenario uncertainty, knowledge uncertainty, operational uncertainty, and behavioral uncertainty.[30] The approach is especially useful where broad-scale climate change cannot be used with confidence in regional climate models or to determine local trends in precipitation. This indicates that instead of taking an optimal decision, implying reliable descriptions of the future, we may rather engage in a process of robust decision-making that would enable best outcomes under a range of future scenarios and worldviews.[31]

**A typical example to illustrate this approach would be a coastal city that faces risk of flooding due to sea-level rise and extreme weather events.** The decision-making under deep uncertainty approach involves framing the problem of reducing flood vulnerability in the city by acknowledging uncertainties like sea-level rise, storm intensity, and urban development. Scenarios are developed to capture various combinations of these uncertainties, informing modeling and analysis to assess impacts on flood risk and adaptation measures. Investment decisions are made by selecting adaptive strategies based on robustness analysis, stakeholder input, and considering factors like effectiveness, feasibility, social equity, environmental impacts, costs, and other co-benefits, followed by iterative monitoring and learning to update strategies over time. This holistic approach helps prioritize investments and

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28 Cambridge Centre for Risk Studies. 2020. *Developing Scenarios for Disaster Risk Reduction*. Cambridge, UK: Cambridge Centre for Risk Studies. Link.

29 For example, see scenario-based probabilistic analysis of Vienna, Austria (SYNER-G 2013). Schäfer, D., A. Bosi, T. Gruber, and H. Wenzel. 2013. *WP 6: Validation Studies Vienna Test Case*. Link.

30 Webber, M. K., and C. Samaras. 2022. *A Review of Decision Making under Deep Uncertainty Applications Using Green Infrastructure for Flood Management.* Earth's Future, no. 10. Link.; McDermott, T. K. J. 2016. Investing in Disaster Risk Management in an Uncertain Climate. Part of the Climate Risk Management, Policy and Governance Book Series (CRMPG). Link.

31 Hallegatte et al. 2012. *Investment Decision Making under Deep Uncertainty - Application to Climate Change.* World Bank. Link.

strategies that enhance the city's resilience to climate change and extreme weather events while promoting sustainable and equitable development.

### Participatory approach

**Surveys, consultations, impact assessments, and many other tools are used to engage key stakeholders to consider their perspectives and needs during the decision-making process.** Stakeholders include citizens, local communities, and civil society organizations. The logic is that those most affected by disasters and the related DRM measures should have a say during the decision-making process. The participation of key stakeholders increases transparency, accountability, and local ownership and contributes to wider acceptance of decisions. The participatory process also facilitates collaboration, trust building, and social cohesion among stakeholders; in rare cases, it may even contribute to conflict resolution. The approach is however more time-consuming and resource intensive, and it might not always be straightforward to reach consensus.[32]

**For DRM investments**, a participatory approach can be useful to incorporate local knowledge and contextual understanding in the prioritization process. This can lead to more robust and evidence-based results and greater ownership and acceptance in and sustainability of DRM investment decisions.

### Rate of Return

**The RoR approach is closely linked to the BCA approach but allows decision-makers to compare different investment options by their rate of financial return.** The prioritization is based on those investments that offer the highest RoR relative to their costs. The rates can be expressed in different ways. The net present value (NPV) is the difference between the present value of expected cash inflows and outflows. The IRR is a metric used in analysis to estimate the benefits of potential investments. This discount rate makes the NPV of all monetary flows equal to zero in a discounted monetary flow analysis. The external RoR further adjusts for inflation and costs of capital. Both the NPV and IRR are indicators of profitability. It is important to note that the RoR only captures financial benefits of an investment and ignores potential social and environmental benefits.[33]

### Cost-effectiveness analysis

**The CEA is used to identify the least-cost option to meet a specific, predefined target or policy objective without necessity of quantifying the benefits.** A CEA is useful for decision-makers if they are primarily concerned about one outcome of interest (for example, resource optimization, cost control, and comparing similar programs). Since CEAs are sensitive to place, scale, and errors in estimates, it may be difficult to precisely compare programs.[34] The CEA can be a useful tool for decision-makers to compare and prioritize DRM investments based on their efficiency and expected outcomes, even when they target different and multiple hazards or have diverse resilience outcomes. Furthermore, the transparent nature of the approach enhances accountability and helps build public trust in DRM investment decisions.

### Analytical hierarchy process

**The AHP offers a technique to structure complex problems by arranging elements of the problem in a hierarchy.**[35] In risk prioritization, the AHP may be used to structure risks and make pairwise comparison to assess risk importance to calculate priority weight of the risks and thereby obtain a risk ranking. Furthermore, sustainability is often considered as an important aspect in evaluating risk prioritization

32 ODI. 2004. "Chapter 8: Participation." In *Good Practice Review - Disaster Risk Reduction*. ODI: London, UK. Link.
33 OECD. 2009. "Chapter 16 Estimating Rates of Return." In *Measuring Capital - OECD Manual*. Paris, France: OECD. Link.
34 Mechler 2016.
35 Bhushan, N., and K. Rai. 2004. *Strategic Decision Making: Applying the Analytic Hierarchy Process*. Link.

indexes. The AHP is a widely implemented in real-world applications as it has proven to be a well-established technique for addressing complex decisions and obtaining a priority ranking of alternatives.[36] While the MCA provides a more flexible and comprehensive approach, the AHP offers a structured method for pairwise comparisons. The choice between the MCA and AHP will depend on the complexity of the decision, the available data and expertise, and the preferences of decision-makers. For example, in Portugal, the AHP model was applied recently to include multiple expert opinions and evaluate flood vulnerability, considering either the community's resilience or exposed elements.[37] In the Philippines, a vulnerability index was used to capture the impact of investments on various sectors in times of disaster to yield the maximum benefits to the entire economy.[38]

### Monte Carlo simulation

**The Monte Carlo simulation is a computational technique used to assess the uncertainty and variability of outcomes in a model or system and in view of various disaster scenarios.** The tool supports evidence-based decision-making, risk assessment, and the identification of effective strategies to mitigate and manage disaster risks. The simulation involves running a large number of scenarios based on input parameters and their probability distributions. The simulation randomly samples values from the input distributions and calculates the corresponding outputs or results. By repeating this process thousands or millions of times, a probability distribution of the output variables is generated, allowing for the assessment of different possible outcomes.[39] This simulation was, for example, used to quantify confidence intervals for three disaster case studies in the United States, confirming previous loss estimates.[40]

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36 Hoang, L. H. G., and T. Takaaki Kato. 2023. "Use of Analytic Hierarchy Process and Four-Component Instructional Design for Improving Emergency Response Exercises." *International Journal of Disaster Risk Reduction* 87: 103583. Link.

37 Murato et al. 2023. "Assessing Vulnerability in Flood Prone Areas Using Analytic Hierarchy Process—Group Decision Making and Geographic Information System: A Case Study in Portugal." Appl. Sci. 13 (8): 4915. Link.

38 See, for example, Yu et al. 2014. "A Vulnerability Index for Post-Disaster Key Sector Prioritization." *Economic Systems Research* 26 (1): 81–97. Link.

39 EC. 2021a. "Chapter 8: Methodologies for Analysing Impacts in Impact Assessments, Evaluations, and Fitness Checks." In Better Regulation Toolbox, 497–606. Link.

40 Smith, A. B., and J. L. Matthews. 2015. "Quantifying Uncertainty and Variable Sensitivity within the US Billion-Dollar Weather and Climate Disaster Cost Estimates." *Natural Hazards* 77: 1829–1851. Link.

# ANNEX 3: Overview of Existing Literature

**Table 21.** Overview of existing case studies reviewed as part of background research

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Albania:** Climate Resilient Road Assets (World Bank) | Prioritization of interventions in resilience of road networks based on vulnerability and economic criteria | Floods, earthquakes, and precipitation and seismic-induced landslides | EURO-CORDEX[1] data set and EM-DAT for data on past hazard events; data from existing rehabilitation projects gathered | Risk analysis and mitigation measures and BCA | Prioritization of mitigation measures into RAMS based on risk and vulnerability assessment |
| **Armenia:** Assessment and Optimization Study of Fire/Rescue Stations in Armenia (World Bank) | Uniform assessment of fire/rescue station buildings for earthquake structural safety and emergency functionality/ response capacity | Earthquake hazard using probabilistic seismic hazard analysis. Floods and soil settlement | Hazard, exposure data available; missions to Armenia to gather data on functionality and response capacity for baseline assessment of fire/rescue stations | Probabilistic seismic risk assessment with retrofit prioritization based on various factors including shared ownership, planned replacement, and flooding/ soil settlement | First seismic risk assessment of this type for Armenia. Important to determine priority schemes for retrofit and modernization of fire/rescue stations given several budgetary options |
| **Bulgaria** and **Greece:** Prioritization frameworks informing NDRMPs (World Bank) | **Bulgaria:** Prioritization of short-, medium-, and long-term DRM investment goals and priorities at the national level, considering multiple stakeholders<br>**Greece:** Prioritization of prevention, preparedness, and response measures for multi-hazards, considering existing and proposed measures | **Bulgaria:** Floods, wildfires, earthquakes, landslides, severe storms, droughts, extreme heat, extreme winter conditions; human, animal, and plant infectious diseases; industrial, nuclear, and transportation accidents<br>**Greece:** Earthquake, flood, WUI, heatwaves and droughts, extreme weather events, landslide, technologic accident, infectious disease, chemical, biological, radioactive and nuclear (CBRN) | **Bulgaria:** Maps and data on multiple hazards and select exposure layers<br>**Greece:** Legal, research, and government documents | **Bulgaria:** Multi-hazard scenario risk assessment and MCA for investment priority prioritization<br>**Greece:** Consolidation of planned and proposed measures as well as financing opportunities to manage multi-hazard risks in Greece | **Bulgaria:** Development of an NDRMP, including multi-hazard investment goals and priorities<br>**Greece:** Development of an NDRMP, including multi-hazard investment goals and priorities |

1 For more details about EURO-CORDEX see https://www.euro-cordex.net/

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Croatia:** Flood risk assessment (INFRARISK project, EC) | Stress test for interdependent infrastructure networks (railways and bridges) under extreme hazard scenarios (low-probability, high-consequence flood events) | Municipalities with high to very high flood and landslide susceptibility | Data on road and rail network and land use from OpenStreetMap;<br>past rainfall and river data from Croatian Hydrological and Meteorological Department; flood hazard data based on 100-year European flood hazard map (publicly available);<br>indirect loss estimation based on data from EU and Croatia transportation authorities | Two-stage stress test for low-probability, high-consequence flood hazard scenarios based on three extreme flood hazard scenarios (qualitative + quantitative) | Identify the railway sections with the most substantial flood risk and disruptions for intervention prioritization; repair of large-scale, multisector transportation networks |
| **France** (Sfetsos et al. 2021) | Assessment of climate resilience to interconnected critical infrastructures | High exposure to wildfires | Compound and cascading fire hazard information using historical data for dry hazards, heatwaves, droughts, and fires across Europe. RCP 4.5 and RCP 8.5 data sets, distribution network data sets | Risk assessment with tabletop input from stakeholders | Important example on co-creation of prioritization schemes for addressing wildfire hazard and risk mitigation for critical infrastructure |
| **Georgia:** Enhancing the Understanding of Earthquake Impacts in Georgia - Study of Seismic Risk to Emergency Response Facilities (World Bank) | Lack of a systematic understanding of emergency facilities' resilience and their ability to continue providing services after a big earthquake event | High seismic hazard and secondary hazards such as landslides | Report on the methodology and findings | Scenario and probabilistic analysis of seismic risk, and resulting estimate of interruption of service provision across the country | Planning for investment across large portfolios of buildings and infrastructure and establishment of resilience hubs, where continued provision of emergency services is a critical objective |

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Greece** (Palaiologou et al. 2021) | Forest management for wildfire risk mitigation and community protection | High exposure to wildfires | Spatial data for fire simulations as well as data gathered for growing stock volume, management status, and socioeconomic attributes | Scenario planning model to explore different strategic approaches to allocate fuel treatment projects and evaluate efficiency and trade-offs. | Scenario-based approach to improve efficiency for wildfire management and operationalizes wildfire management with considerations of safety, social, and economic priorities |
| **Greece:** Risk Assessment of Network Systems in the City of Thessaloniki (SYNER-G project, EC) | Seismic risk assessment of a complex, multisector network (roads, building stock, water supply system, and electric power network) in urban area with intra-system interdependencies considered | High seismic risk region with five seismic zones with all possible magnitudes ranging between M5.5 and M7.5 | Seismic risk data based on results from three SHARE European research projects; GIS-based digital data of transportation network, health service locations, and administrative districts of Thessaloniki | Stochastic approach with seismic stimulation and connectivity analysis; GIS-based accessibility analysis | Prioritization of intra-system networks based on their connectivity losses and correlation of components performance to the total systems' functionality |
| **Ireland:** Prioritization of Flood Risk Reduction Interventions (EC 2021, National) | Prioritization of interventions with simple, participatory approaches and considering nonmonetary, broader benefits | Flood | National and local FRMPs<br><br>Qualitative assessment of benefits | Qualitative scoring of proposed / existing flood risk management measures | Decision support system (MCA) for prioritizing/ monitoring flood risk management measures at the local and national levels |
| **Italy:** 2010-2016 National Plan for Seismic Risk Prevention in Italy (World Bank/EC and National) | Informing national seismic risk reduction programs through prioritization of different assets, including economic/financing criteria | Higher-risk municipalities in Italy, whose 475-year return period peak ground acceleration on stiff soil exceeded 0.125 g | Data on investments are available from the Civil Protection Department upon request | The investment program was retrospectively analyzed in Phase 1 World Bank study by employing triple dividend benefit-cost analysis framework to determine the cost-effectiveness of the investment with respect to future risk. | Large retrofit investment program that includes thousands of private/ residential and public buildings |

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Italy:** Risk assessment of a Road Network of Calabria region (SYNER-G project, EC) | Lack of a systemic seismic vulnerability assessment for estimation of losses and prioritization of complex, interdependent systems (road network + health facilities within the network); lack of traffic demand models and assessments for a road network during seismic events | High seismic risk and secondary hazards such as landslides | Seismic data from Italian Database of Individual Seismogenic Sources (DISS); data on the road network from database DBPrior10k, provided by the Cartographic Center of Calabria region | Connectivity analysis | Prioritization in risk assessment based on road types and travel disruptions to health facilities |
| **Italy:** Risk Assessment of the L'Aquila Gas Distribution System (SYNER-G project, EC) | Lack of quantitative, systematic seismic analysis and post-earthquake evaluations of gas system compared to other lifeline systems | High seismic risk region with a Mw 6.3 earthquake occurring in April, 2009 | Empirical data on the L'Aquila 2009 earthquake;<br>data on maintenance/ repair activities obtained from 500+ technical<br>reports from Enel Rete Gas and GIS database;<br>data input for the seismic hazard characterization based on previous studies | Probabilistic seismic and geotechnical hazard analysis | Buried components of the network and their post-disaster repairment were prioritized and emphasized in the risk assessment |

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Italy:** Seismic Risk Assessment (INFRARISK project, EC) | Stress test for interdependent infrastructure networks (roads, bridges, and tunnels) under extreme hazard scenarios (low-probability, high-consequence seismic hazard events) | High seismic and earthquake-triggered landslide risk in the province of Bologna, with high landslide susceptibility and peak ground acceleration between 0.3–0.4 g or exceed 0.4 g for 10 percent exceedance probability in 50 years | Data on road network and land use available in OpenStreetMap and Google maps; seismic hazard map developed by EU FP7 project share, landslide susceptibility map developed by European landslide expert group (publicly available); data on fragility functions based on SYNER-G project database | Stress test for low-probability, high-consequence seismic hazard scenarios | Identifying the most vulnerable network elements for intervention prioritization; repairment of large-scale, multisector transportation networks |
| **Portugal** (Alcasena et al. 2021) | Wildfire risk assessment considering community exposure, urban fabric makeup, and adaptation capacity. | High exposure to wildfires | Fire ignition and transmission data, structure density data, census/population/socioeconomic data, and CP resource data | Community adaptation and vulnerability prioritized by age > 65, purchasing power by capita, number of firefighters, and fire intensity and fire recurrence interval. | Considering particular demographics as part of the study contextualizes typical fire risk analysis with important social trends. Assessing capacity can inform which mitigation measures can be employed in certain areas. |
| **Portugal** (Nunes et al. 2023) | Looked at the spatial variations in wildfire hazard at WUI | Exposure to wildfires | | Using WUI as a spatial risk analysis unit to assess a location's susceptibility to wildfires was overlaid with wildfire risk models | By applying this method, locations with higher levels of hazard can be identified, which enables guiding the design of spatially targeted strategies in management, preparedness, and mitigation plans. |

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Romania:** Enhancing Seismic Resilience of Critical Infrastructure (World Bank) | Consistent analytical and prioritization framework needed for application to various types of critical infrastructure in one country (education, emergency response buildings) | High seismic risk and exposure to numerous other hazards (floods, landslides, wildfires, droughts) | Existing working relationships with CP; previous numerous analytical projects and data gathered; technical capacity to collect additional data | Existing analytical frameworks applied for preparation of investment programs in Romania; focus on earthquake with probability analysis | Prioritization of infrastructure investments based on risk information |
| **Romania:** flood risk Management in the Romanian Electric Power System (Marinescu et al. 2017) | Large-scale, national-level quantitative assessment of nuclear power system based on long-term, real-world data | Flood and other extreme weather-triggered hazards | Data on flood damage provided by National Operational Center of the General Inspectorate for Emergency Situations | Geo-referential modeling and probability analysis, with national critical infrastructure, their interconnections, and connections with other countries' critical infrastructure taken into account | Result could help with the prioritization of mitigation measures that could bring the power system back to normal operation conditions in the shortest time after an extreme weather event occurs; assist the development of hazard resilient power stations and networks at design stage (either avoid exposure to disaster risks or take necessary precautions) based on the risk stimulation and data on past negative events |

| CASE STUDY NAME | DRM ANALYTICAL GAP | HAZARDS COVERED AND EXPOSURE | DATA AVAILABLE | METHODOLOGICAL APPROACH | RELEVANCE |
|---|---|---|---|---|---|
| **Spain** (Alcasena et al. 2019) | Considering scattered homes susceptible to wildfire hazard in the WUI but understudied in general | High exposure to wildfires | Historic fire ignition and occurrence data | Fire simulation modeling to assess exposure metrics. These were combined with land use maps and historical fire occurrence data to prioritize different fuel and fire management options at the municipality level. | Supporting ability to develop localized programs to build defensible space and improve self-protection; facilitation of landscape planning |

**Table 22.** Prioritization frameworks of interventions for wildfires - an overview

| MEASURE | TYPE OF INTERVENTION | PROCESS OF PRIORITIZATION | EXAMPLES (SOURCE) |
|---|---|---|---|
| **Prevention** | Fuel breaks and road network | Italy: Regional Fire Management Plan (under Art. 3, Law 353/2000): road and fuel break network for firefighting<br>Portugal: The 2020–2030 Fuel Management Plan, with areas of prioritization for wildfire management in (a) structural prevention, (b) surveillance, detection, and inspection, and (c) suppression<br>Türkiye: Extensive road networks, fuel breaks, and water impoundments for forest fire management | Italy (San-Miguel-Ayanz, J. et al. 2021), Portugal (AGIF 2020), Türkiye (Elvan et al. 2021) |
| **Prevention** | Managing WUIs | Italy: WUI raster map<br>Spain: Legal requirement for communities to establish security buffer zone and self-protection plan in WUI | Italy (San-Miguel-Ayanz et al. 2022), Spain (EFI 2022) |

| MEASURE | TYPE OF INTERVENTION | PROCESS OF PRIORITIZATION | EXAMPLES (SOURCE) |
|---|---|---|---|
| **Prevention** | Managing landscapes/fuel management | Türkiye: Establish fire-stopping zones and separation zones based on different types of areas (for example, fire-stopping zones in young and fire-sensitive forests, separation zones between settlements and forest areas, or between agricultural land and forest areas)<br>Italy: ABCD program, an innovative fire prevention program by strategic fuel management involving private owners and citizens<br>Spain: RAPCA programme (directed by the General Directorate of Management of the Natural Environment), a payment reward scheme for shepherds who engage in biomass control and fuel break maintenance<br>Spain: Dry vegetation and fuel management by grazing animals in wildfire-prone areas | Türkiye (Schmuck et al. 2011), Italy (San-Miguel-Ayanz et al. 2020), Spain (EFI 2020) |
| **Prevention** | Increasing forest resilience/forest management | Austria: Forest Fund Act 2020 investment and relief package and recommendations to forest owners/managers to increase forest resilience and adaptation based on granular forest fire hazard; silviculture adaptation strategy and climate-resilient and sustainable forest management<br>North Macedonia: Annual Operational Plan for forest fire management was created by the PC 'National forests' and its subsidiaries<br>Ukraine: Official Forest Fire Management Plan (Under the Grant Agreement №18-IG-11132762-423)<br>Portugal: Legal and institutional framework for the establishment of forest intervention zones for forest management and forest fire protection<br>Norway: National guidelines for forest management dispatched to forest operators and local fire departments<br>Poland: Small-scale retention and protection for both wildfire and water erosion prevention<br>North Macedonia: National adaptation strategy and plans for forest management under climate change | Austria (San-Miguel-Ayanz et al. 2022; EUSTAFOR), North Macedonia (San-Miguel-Ayanz et al. 2022), Ukraine (San-Miguel-Ayanz et al. 2022), Portugal (EFI 2022), Spain (Kassam 2022), Norway (EUSTAFOR 2020), Poland (EUSTAFOR 2020), North Macedonia (San-Miguel-Ayanz et al. 2019) |
| **Prevention** | Upgrading buildings for fire prevention | Greece: Regulation on Fire Protection of Buildings, which focuses on improvements over the inspection mechanism and fire resilience of buildings | Greece (ELIPYKA 2018) |
| **Prevention** | Resilience of interconnected systems (critical infrastructure) | Türkiye: Improvement over road resilience by planting fire-resistant species along roadsides<br>Greece: Lifeline infrastructure proofed against fires, with five management priorities tested in three scenarios<br>France: Climate resilience of interconnected critical infrastructures to forest fires, with infrastructure business continuity and societal resilience being considered in the prioritization framework | Türkiye (San-Miguel-Ayanz et al. 2022), Greece (Palaiologou et al. 2021), France (Sfetsos et al. 2021) |

| MEASURE | TYPE OF INTERVENTION | PROCESS OF PRIORITIZATION | EXAMPLES (SOURCE) |
|---|---|---|---|
| **Prevention** | Early warning and forecasting | Serbia: The Forest Directorate (Ministry of Agriculture, Forestry, and Water Management)'s forest fire occurrence probability modeling and mapping based on the Random Forest Method<br>Poland: State Forest National Forest Holding 's communication and alarm network<br>Sweden: Improved fire risk forecast model that shows the evolution of the fire risk parameters based on hourly data<br>Hungary: National forest fire information system (with fire cause scheme developed by JRC incorporated)<br>Spain: Centre for the Coordination of National Information on Forest Fires (CCINIF) under Royal Decree-Law 11/2005: providing real-time monitoring and information on the evolution of the risk of forest fires to public administrations<br>Lithuania: Uniform system on forest fire risk classification and forest fire danger map<br>Sweden: Automatic monitoring system after lightning storms | Serbia (San-Miguel-Ayanz et al. 2022), Poland (2020), Sweden (San-Miguel-Ayanz et al. 2022), Hungary (San-Miguel-Ayanz et al. 2022), Spain (San-Miguel-Ayanz et al. 2022), Lithuania (San-Miguel-Ayanz et al. 2017), Sweden (Enoksson 2011) |
| **Prevention** | Fire bans and permits | Sweden: Fire bans issued at the county or municipal level, with prioritization given to periods when weather conditions increase fire risks | Sweden (MSB 2019) |
| **Preparedness** | Pre-positioning resources/ equipment | Ireland: Fire suppression activities and equipment at the local level<br>North Macedonia: Checking and updating equipment for extinguishing fires and the condition of the protection and rescue forces based on ex post assessment of previous year wildfire events, conducted at national level by the Department for Prevention, Planning, and Development | Ireland (San-Miguel-Ayanz et al. 2022), North Macedonia (San-Miguel-Ayanz et al. 2022) |
| **Preparedness** | Water management for fire prevention | Poland: Dedicated wells for extinguishing and water management<br>Spain: The Guardian project, which uses recycled water to constitute the defensive barrier for fire mitigation and protection between forest and urban areas | Poland (EUSTAFOR 2020), Spain (Pastor 2020) |

| MEASURE | TYPE OF INTERVENTION | PROCESS OF PRIORITIZATION | EXAMPLES (SOURCE) |
| --- | --- | --- | --- |
| **Preparedness** | Public awareness and information | Hungary: FIRELIFE project, which develops an up-to-date communication framework plan that provides targeted information and messages to prioritized groups that may cause wildfires negligently or intentionally<br>France: Information campaign at the NUTS3 level and across the NUTS1 level to publicize preventive regulations and safety regulations; national inter-ministerial (agriculture, environment and interior) information campaign for wildfire prevention and control<br>Portugal: 'Portugal Chama' ('Portugal is Calling') national campaign promotes behaviors and practices to reduce ignitions and enhance territory resilience to fires, with a focus on educating the public on the most relevant causes of rural fires<br>North Macedonia: National and regional level public awareness campaign for forest fires prevention under the slogan 'Let's be prepared'<br>Switzerland: Federal prevention strategy focuses on prevention and information and is implemented through collaboration between the Cantons (states) with the confederation (federal state)<br>Greece: Local community mobilization in fuel management and forest rehabilitation work and awareness raising<br>Norway: Local and national information and awareness-raising campaign and school children education at the local scale<br>Ireland: National-scale media statements and fire danger notice and local-scale communication with landowners on improvements over behavior and attitudes toward fire risks and uses<br>Switzerland: Federal forest fire strategy that prioritizes prevention and information | Hungary (Schmuck et al. 2015), France (San-Miguel-Ayanz et al. 2022), Portugal (San-Miguel-Ayanz et al. 2022), North Macedonia (San-Miguel-Ayanz et al. 2022), Switzerland (San-Miguel-Ayanz et al. 2020), Greece (EFI 2022), Norway (EUSTAFOR 2020), Ireland (San-Miguel-Ayanz et al. 2019), Switzerland (San-Miguel-Ayanz et al. 2019) |
| **Preparedness** | Training and capacity building | Austria: Special training courses for forest fire fighting, with a prioritization of actions in the mountain areas and actions that involve helicopters and airplanes<br>Italy: Law 155/2021 to enhance coordination, forecasting, and response capacities to wildfires; a national coordination plan for technological updating in capacity building<br>Portugal: ANEPC's operational training program with prioritized actions such as implementing operations management system and combating techniques using manual and mechanical tools; the National Authority for Civil Protection's prioritization strategy in emergency response and rescuing<br>Norway: Mandatory forest fire course for local fire departments<br>Spain: Training course for personnel working on fire management, including courses on fire causes and risks, safety and accident investigation, and fire extinction | Austria (San-Miguel-Ayanz et al. 2022), Italy (San-Miguel-Ayanz et al. 2022), Portugal (San-Miguel-Ayanz et al. 2020), Norway (EUSTAFOR, 2020), Spain (Schmuck et al. 2013) |

| MEASURE | TYPE OF INTERVENTION | PROCESS OF PRIORITIZATION | EXAMPLES (SOURCE) |
| --- | --- | --- | --- |
| **Recovery** | Reforestation and forest restoration | Italy: 'Piano Straordinario Incendi Boschivi' program 2017, which identifies priority areas for prevention and restoration activities and fundings based on factors like forest ecosystem services, fire severity, and a participatory program involving local populations in territories affected by major wildfire events<br>Portugal: Areas with water lines are prioritized, and within these areas, maintenance or recovery of riverside galleries adapted to local conditions is prioritized<br>Czech Republic: Restoration of forests affected by climate change, with prioritization based on the size of the forest<br>Spain: Restoration of burned forests in protected areas, with prioritization standards for the selection of plants based on genetic origins and morphological qualities | Italy (San-Miguel-Ayanz et al. 2018), Portugal (Portugal Presidency of the Council of Ministers 2021), Czech Republic (EUSTAFOR 2020), Spain (EUSTAFOR 2020) |

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