Management of Earthquake Risk in the EUROPEAN UNION

TAFF Technical Assistance Financing Facility for Disaster Prevention and Preparedness

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ACRONYMS

ASP	Adaptive Social Protection
ATC	Applied Technological Council
BBB	Building Back Better
DRF	Disaster Risk Financing
DRM	Disaster Risk Management
DRMKC	Disaster Risk Management Knowledge Centre
EBB	Earthquake Brace and Bolt
EC8	Eurocode 8
ECPP	European Civil Protection Pool
EEA	European Economic Area
EEW	Earthquake Early Warning
EIOPA	European Insurance and Occupational Pensions Authority
EMSC	European-Mediterranean Seismological Centre
EPPO	Earthquake Planning and Protection Organization
ERCC	Emergency Response Coordination Centre
ESHM20	2020 European Seismic Hazard Model
ESRM20	2020 European Seismic Risk Model
EU	European Union
EUSF	European Union Solidarity Fund
EWS	Early Warning System
EWSS	Emergency Warning Satellite Service
FEMA	Federal Emergency Management Agency
GDACS	Global Disaster Alerts and Coordination System
GFDRR	Global Facility for Disaster Reduction and Recovery
GIES	General Inspectorate for Emergency Situations
GSCP	General Secretariat for Civil Protection
GTM	Global Tsunami Model
INGV	Institute of Geophysics and Volcanology (*Instituto Nazionale Di Geofisica e Vulcanologia*)
JRC	Joint Research Centre
MDPWA	Ministry of Development, Public Works, and Administration
METIS	Seismic Risk Assessment for Nuclear Safety
MMI	Modified Mercalli Intensity
NIEP	National Institute for Earth Physics
NRA	National Risk Assessment
NSPP	National Seismic Prevention Plan
NSRRS	National Seismic Risk Reduction Strategy
PPP	Public-Private Partnership
UCPM	Union Civil Protection Mechanism
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAR	Urban Search and Rescue

KEY TERMS

Earthquake risk is understood as the combination of seismic hazard (for example, the frequency of earthquake occurrence, the strength of ground shaking given an earthquake), exposure (for example, the number of people exposed, the value of assets exposed), and vulnerability (for example, the susceptibility of assets to damage, the ability of populations to cope with earthquake effects).

Hazard: A potentially destructive physical phenomenon, such as a natural hazard (e.g., earthquake, wildfire).

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

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.

Earthquake magnitude is a quantitative measure of the size or energy released by an earthquake at its source. It is determined using seismic data and reflects the amplitude of seismic waves recorded by seismographs. The most common magnitude used today is the moment magnitude scale (Mw), which largely replaced older scales such as the Richter scale. Unlike intensity, which measures the observed effects of an earthquake at specific locations, magnitude provides a standardized measure of an earthquake's overall strength, regardless of where it is measured.

Earthquake shaking intensity measures the strength of ground shaking at a specific location and its effects, such as damage or human perception. Intensity varies with distance from the epicenter and local site conditions. In Europe, a commonly used intensity scale is the European Macroseismic Scale (EMS-98), which ranges from I (not felt) to XII (completely devastating) and is based on observed effects on people, buildings, and infrastructure. Another widely used intensity scale is the Modified Mercalli Intensity (MMI) scale, which is used in the United States and other regions. Quantitative measures like Peak Ground Acceleration and similar parameters are also used in engineering design and seismic assessment and are based on ground motion recorded by instruments.

Secondary perils: Also known as earthquake-triggered perils, are hazards that are triggered by the primary earthquake event. These include landslides, soil liquefaction, tsunamis, and fire following, which can significantly increase the overall damage, losses and disruption.

Earthquake risk assessment: A process that combines hazard, exposure, and vulnerability information to assess expected infrastructure and human losses after an earthquake. Typically, this involves probabilistic calculations considering a range of hypothetical earthquake scenarios.

Microzonation: Microzonation studies involve geological and geotechnical surveys and analysis, which are used to create detailed maps of seismic hazards in an area. This information can be incorporated into building codes, inform territory and land use management, and guide post-earthquake reconstruction.

Building code: A set of ordinances or regulations and associated standards intended to regulate aspects of the design, construction, materials, alteration, and occupancy of structures necessary to ensure human safety and welfare, including resistance to collapse and damage.

Early warning systems (EWS) are integrated systems that disseminate timely and meaningful information to users threatened by a hazard. These systems can enable protective actions to reduce harm posed by the hazard. Some examples of EWS include sirens, text messages/SMS, and TV or radio broadcasts. Additionally, different hazard types may require different technical capabilities and infrastructure. For earthquakes, EWS typically provide post-event information such as earthquake details and impact estimations, public advisories and aftershock potential. EWS can also include earthquake early warning (EEW) which are alerts that give imminent notice before shaking begins, but these are not widely implemented.

Earthquake early warning (EEW) involves detecting initial ground shaking and rapidly notifying end users before imminent, stronger ground shaking. The lead time between notification and stronger ground shaking varies by location, depending on factors such as the density of seismic stations in the area, the distance from the epicenter, and the data telemetry/EEW algorithm performance. While EEW can be a part of the EWS, they are highly specialized and location specific and are not widely available.

Coping capacity: The ability of people, organizations, and systems, using available skills and resources, to manage adverse conditions, risks, or disasters.[1]

[1] Mysiak, J., V. Casartelli, and S. Torresan. 2021. *Union Civil Protection Mechanism - Peer Review Programme for Disaster Risk Management: Assessment Framework*. Euro-Mediterranean Center on Climate Change (CMCC). Link.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including ensuring the preservation, restoration, or improvement of its essential basic structures and functions.[2]

'Build back better' (BBB) principle: The use of the recovery, rehabilitation, and reconstruction phases after a disaster to increase the resilience of nations and communities by integrating disaster risk reduction measures into the restoration of physical infrastructure and societal[3] systems and into the revitalization of livelihoods, economies, and the environment.

Damage: Total or partial destruction of physical assets existing in the affected area. Damage occurs during and after the disasters and is measured in physical units (that is, square meters of housing, kilometres of roads, and so on).[4]

Losses refer to indirectly quantifiable losses (declines in output or revenue, impact on well-being, disruptions to flow of goods and services in an economy), or additional operational costs associated with response and initial repairs.[5]

Reconstruction: The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities, and livelihoods required for the full functioning of a community or society affected by a disaster, aligning with the principles of sustainable development and BBB to avoid or reduce future disaster risk.

Rehabilitation: The restoration of basic services and facilities for the functioning of a community or society affected by a disaster.

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[2] World Bank and European Commission. 2021. *Investing in Disaster Risk Management in Europe Makes Economic Sense, Background Report. Economics for Disaster Prevention and Preparedness*. Link.

[3] The term 'societal' should not be interpreted as a political system of any country.

[4] World Bank. 2021.

[5] Global Facility for Disaster Reduction and Recovery, website. Link.

EXECUTIVE SUMMARY

Several countries in the European Union (EU) face significant earthquake risk, primarily due to seismic hazard levels and aging infrastructure. Unlike many other natural hazards, earthquakes occur without warning, limiting the ability to evacuate people and protect lives. At the same time, decades can pass between large earthquakes, leading to a decline in public awareness and policy attention to the risk. When large earthquakes do occur, they can cause significant damage and loss, often requiring several decades for the affected areas to recover. Between 2000 and 2020, earthquakes caused more than €60 billion in direct damage to EU Member States, confirming their status as one of the costliest natural hazards in the region.[6] All these factors make long-term planning, risk reduction, prevention, and preparedness efforts essential to reducing the impacts of earthquakes.

This report summarizes the results of a rapid review of earthquake risk and risk management capacity in the EU, highlighting potential risk management priorities to inform policy dialogue and future research. The review considers capacity across multiple dimensions, including governance, understanding of earthquake risk, risk reduction and mitigation, early warning and public awareness, preparedness and emergency response, recovery and post-disaster financing, and cross-cutting topics such as social resilience and the role of the private sector. Each chapter reviews the current arrangements, key challenges, and opportunities across the EU for each of these dimensions, drawing on available information. This review aims to provide an EU-wide perspective on earthquake risk management, using EU Member States as examples but not providing an in-depth analysis of each EU Member State.

[6] This is a consensus statistic based on two sources: EU Solidarity Fund Interventions since 2002 (as of January 2025). Link, and EM-DAT, CRED/UCLouvain, 2024, Brussels, Belgium. Link.

KEY MESSAGES

The following key messages can be highlighted based on the review of earthquake risks and risk management capacity in the EU:

1. Earthquakes remain a major risk in the EU, yet they are not consistently prioritized. Approximately 35 percent of the European population is exposed to moderate to high seismic hazard.[7] Yet, a recent survey found that only 13 percent of respondents across the EU feel exposed to geological disasters such as earthquakes.[8] Despite significant damage in recent events and the historical precedence for catastrophic damage, earthquakes often receive less attention from policy makers and the public compared to more frequent hazards. This makes long-term strategic planning essential to keep earthquake risk reduction a priority at both national and EU levels.

2. The primary driver of earthquake risk in Europe is its aging infrastructure. Much of the building stock and infrastructure in the EU predates modern seismic design codes or was built to older, insufficient standards, including 40 percent of buildings in seismic zones.[9] For example, the housing sector bears a significant share of potential damage and losses, which could displace residents and create recovery challenges. Risk reduction in the public and private building stock requires both immediate and long-term investments, supported by strategic planning and prioritized funding.

3. Buildings and infrastructure can be designed or retrofitted to reduce damage and protect people. Although seismic hazards cannot be reduced in a given area, the implementation and enforcement of Eurocode 8 (EN 1998 or EC8) ensure that new construction is designed to be earthquake-resistant and guide the retrofit of existing buildings. Risk-based land use planning can also help avoid creating new earthquake risks, including those posed by secondary perils such as landslides or liquefaction.

4. A significant share of critical entities across the EU are exposed to seismic hazards, which may amplify disaster impacts—but this risk remains insufficiently addressed. Damage to critical entities (for example, emergency response facilities, hospitals, transport networks, utility systems) can hamper response and disrupt essential functions. Moreover, these disruptions can lead to cascading effects (for example, disrupted water supply limits the ability to extinguish fires, loss of communication or blocked roads prevent necessary emergency care). Yet, limited data and systemic analysis of critical entities hinder a full understanding and management of these risks.

5. Local action is key to reducing seismic risks, yet it is frequently hindered by capacity and resource constraints. While EU or national strategies may promote earthquake resilience, implementation requires actions and investments at the local administrative levels. At the same time, local governments are often under-resourced or may have limited capacity to screen and prioritize buildings for upgrading, as well as to finance and monitor implementation.

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7 Crowley, Helen, Venetia Despotaki, Daniela Rodrigues, Vitor Silva, Dragos Toma-Danila, Evi Riga, Anna Karatzetzou, et al. 2020. "Exposure Model for European Seismic Risk Assessment." *Earthquake Spectra 36* (1_suppl): 252–73. Link.

8 European Commission. 2024. *Eurobarometer. Disaster risk awareness and preparedness of the EU population*. Link.

9 Butenweg, C., H. Gervasio, K. Gkatzogias, V. Manfredi, A. Masi, D. Pohoryles, G. Tsionis, and R. Zaharieva. 2022. *Policy Measures for Seismic and Energy Upgrading of Buildings in EU Member States*. Publications Office of the European Union. Link.

6. **Effective prioritization is needed to address the vast needs posed by the vulnerable building stock.** The percentage of buildings potentially vulnerable to earthquakes is substantial, and it is not feasible to retrofit or reconstruct them all simultaneously. Instead, strategies to rapidly screen and assess buildings or other infrastructure are required to prioritize which to retrofit or reconstruct, and in what order. Such strategies also allow for efficient short-, medium-, and long-term risk reduction investment planning.

7. **Opportunities to integrate seismic retrofit with other building upgrades are not yet pursued systematically and at scale**. Several existing programs in the EU promote energy efficiency upgrades. However, only a few countries have taken action to systematically integrate and monitor seismic retrofitting investments as part of such programs.

8. **Effective earthquake risk management requires strong population risk awareness and individual risk ownership**. The infrequency of earthquakes can lead to lower risk perception, limited preparedness, and reluctance to undertake risk reduction efforts, especially in countries that have not recently experienced a large event. Sustained investment is needed to build a culture of awareness and incentivize individuals to take initiative, such as retrofitting their homes, purchasing insurance, and learning how to respond when shaking begins.

9. **The lack of national post-disaster recovery frameworks has led to reliance on ad hoc measures, with current disaster risk financing (DRF) mechanisms being inadequate for earthquakes**. Countries have largely been reactive, rather than proactive, in their approach to post-earthquake recovery and reconstruction. This creates administrative delays and decreases transparency about recovery actions. In the aftermath of earthquakes, the vast majority of recovery costs are borne by national budgets, households, and businesses, with over 96 percent of liabilities covered through ad hoc financing across the EU.[10] Limited insurance penetration rates in high seismic risk countries exacerbate government liabilities. Some EU instruments (for example, the EU Solidarity Fund and cohesion policy funds) can provide complementary support for recovery and reconstruction efforts, but they are not designed to cover the full scale of losses typically incurred.

10. **Inconsistent and incomplete damage and loss reporting create uncertainties about recovery needs and financial liabilities**. While promising initiatives exist to report disaster damage and losses in the EU, estimation methods vary widely, and higher-quality national data or aggregate insurance data are not incorporated. Furthermore, disaggregated data to highlight potential discrepancies across population subgroups are largely nonexistent.

[10] World Bank. 2021a. *Financial Risk and Opportunities to Build Resilience in Europe. Economics for Disaster Prevention and Preparedness*. World Bank. Link.; World Bank. 2024a. *Financially Prepared - The Case for Pre-Positioned Finance in European Union Member States and Countries under EU Civil Protection Mechanism.* World Bank. Link.

PRIORITIES GOING FORWARD

The EU and its Member States should prioritize actions, reforms, and investments to manage earthquake risk across various dimensions.

These may include areas summarized below:

1. **Develop or strengthen earthquake governance frameworks and national earthquake risk reduction strategies**. Establish frameworks to clarify roles, streamline cross-sector coordination, and incorporate seismic risks into broader disaster and climate agendas. Enable local governments to scale up risk reduction activities by providing roadmaps that guide them through available technical, financial, and regulatory support.

2. **Scale up and accelerate seismic upgrading programs, prioritizing retrofit or reconstruction of critical entities and housing**. Guidance should be provided to help national and local governments prioritize interventions through rapid visual screening and initial assessment before conducting the detailed assessment required to design retrofits. Factors to consider in prioritization might include life safety risks, criticality (for example, occupancy type, importance of continued functionality post-earthquake), and feasibility (for example, cost, time). Novel incentives and standardized solutions may additionally be required to increase the uptake of retrofits for private buildings, with opportunities also for private sector engagement.

3. **Leverage synergies with energy efficiency and climate adaptation**. Integrating seismic upgrades with energy efficiency measures or functional and accessibility improvements can help ensure longer-term resilience and optimize investments by providing a range of co-benefits.

4. **Strengthen data-driven earthquake risk management**. At local levels, building inventories, microzonation studies, and risk assessments can help integrate risk information into planning. Standardizing loss and damage reporting while integrating these datasets into EU-wide platforms could foster more effective risk reduction planning as well as preparedness and emergency response.

5. **Continue supporting earthquake and secondary perils research**. Sustaining earthquake and earthquake-triggered perils research can ensure that risk assessments are realistic and support holistic risk reduction strategies. Promising initiatives to advance understanding of secondary perils exist, but additional research is required for secondary perils across hazard, vulnerability, and risk assessment.

6. **Promote comprehensive earthquake risk communication strategies, increase population preparedness, and strengthen early warning systems**. Earthquake risk communication strategies should consider ongoing campaigns using modern, trusted channels to deliver accessible information tailored to different audiences and demographics, including vulnerable populations. Population preparedness requires awareness of risks and practical strategies to increase self-sufficiency in the first 72 hours after an earthquake. To strengthen early warning systems, including earthquake early warning where feasible, steps can be taken to modernize seismic monitoring, improve alert delivery, and ensure integration with emergency protocols and public education efforts.

7. Strengthen recovery legislation and capacity while promoting comprehensive DRF strategies. Enacting flexible recovery frameworks that designate coordinating authorities and streamline administrative processes can balance the desire for timely reconstruction with BBB practices that reduce future risks. Comprehensive DRF strategies reduce dependence on ad hoc funding and ensure timely and reliable financial resources for recovery efforts with a risk-layering approach.

8. Unify guidance on post-earthquake damage inspection and building safety classification (tagging). By leveraging existing national approaches for post-earthquake safety inspections and tagging, the development of a more unified EU-level guidance can enable a training and certification program that supports cross-border deployment.

9. Scale up adaptive social protection and insurance solutions. Integrating social protection into disaster risk management and climate adaptation policy frameworks and operationalizing social protection tools can provide flexible, scalable support for vulnerable households.

10. Mobilize private sector partnerships and innovation. Encouraging collaboration with businesses for technology transfer, greater engagement in risk reduction, continuity planning, and risk transfer solutions may enhance earthquake resilience and speed up post-earthquake economic recovery.

INTRODUCTION

This report is part of a series aimed at improving understanding of the needs and priorities for disaster resilience investments focusing on two natural hazards: wildfires and earthquakes. The broader objective is to provide actionable insights and recommendations to help the European Union (EU), and its Member States to make informed, strategic investments to enhance resilience against wildfires and earthquakes.

This report focuses on earthquakes and describes current risk trends, risk management capacity, and investment needs and recommended approaches relevant EU-wide.[11] The note is complemented by three separate country-specific case studies of earthquake risk management in Croatia, Cyprus, and Romania.

This report provides a rapid overview based on existing information and data. Consultations with a range of relevant national and EU organizations and researchers have been conducted to improve understanding of key areas listed above. The note can serve to inform policy dialogue and future research.

The analysis is structured following the Union Civil Protection Mechanism (UCPM) Peer Review Assessment Framework.[12] The report's scope considers the following disaster risk management (DRM) elements, with a focus on earthquake risk:

[11] Overseas Countries and Territories are not considered.
[12] Mysiak, Casartelli, Torresan. 2021.

1. **Governance of risk management** considers the overall governance framework for earthquake risk management, including dedicated strategies, institutional frameworks, coordination mechanisms, and financing strategies.

2. **Understanding risk** examines the identification, analysis, evaluation, communication, and capacities associated with assessing earthquake risks.

3. **Risk prevention, reduction, and mitigation** explores legislative reforms, development and enforcement of building codes, and integration of hazard considerations into land planning documents, as well as retrofitting efforts and administrative capacities related to risk prevention.

4. **Early warning and public awareness** examines the processes and early warning systems (EWSs), including the potential for earthquake early warning (EEW), as well as public awareness campaigns that enable protective actions to be taken from such systems.

5. **Earthquake preparedness and emergency response** focuses on actions taken in the immediate aftermath to days or weeks after an event, as well as activities that bolster that capacity.

6. **Recovery, reconstruction, and post-disaster financing** covers the processes and actions taken after a disaster event, including damage assessment, restoration efforts, and recovery planning.

7. **Cross-cutting topics**: social resilience and inclusion explores approaches to address the disproportionate impact of disasters on vulnerable populations, with special focus on people with disabilities. Meanwhile, private sector covers relevant stakeholders' involvement in the context of earthquake risk management, including building owners and property managers, insurance companies, business owners, utility providers, construction and engineering firms, but also civil society organizations, and so on.

EARTHQUAKE RISK OVERVIEW

This chapter provides a brief overview of earthquake risk in the EU, drawing upon available data and information, focusing on earthquake risk statistics and estimates. This includes an overview of earthquake hazard and secondary perils, impacts from past earthquakes, and future earthquake risks and risk drivers.

Earthquake hazards and secondary perils

Although strong earthquakes are infrequent, they are among the deadliest and costliest natural hazards, and many EU Member States are exposed to significant earthquake risk. The 2020 European Seismic Hazard Model (ESHM20) provides a harmonized and up-to-date view of seismic hazard across Europe.[13] Results indicate that several EU Member States have moderate to high levels of seismicity, such as Cyprus, Greece, Italy, Romania, Croatia, Bulgaria, Portugal, Spain, France, Belgium, and Germany (see Figure 1). nearly all areas have some level of seismic hazard, meaning that earthquakes could occur in any of the EU Member States, as seen in the 2008 M4.3 Skåne County earthquake in Sweden and the 2006 M4.8 Beregdaróc earthquake in Hungary. Furthermore, human activities can induce seismicity even in areas that are not tectonically active. Some examples include induced seismicity linked to gas extraction in the Netherlands (for example, the Groningen gas field) and mining-related seismic events in Poland (for example, in Upper Silesia).

Earthquakes result in ground shaking that can damage buildings and infrastructure but may additionally trigger secondary perils such as tsunamis, liquefaction, landslides, fires, and surface ruptures. These secondary perils often exacerbate damage and loss.

- Liquefaction occurs during an earthquake when loose, water-saturated soil loses its strength and behaves like liquid, causing buildings and roads to sink, tilt, or crack. Recent earthquakes such as the 2012 M_w6.1 Emilia-Romagna (Italy) earthquake and the 2014 M_w6.1 Cephalonia (Greece) earthquake both triggered liquefaction.[14]

- Tsunamis are large sea waves triggered by sudden sea floor displacements and can affect coastlines along the Northeast Atlantic and Mediterranean Seas. Areas in the EU with the highest tsunami risk include Cyprus, Greece, and the Gulf of Cádiz (Portugal and Spain).[15] However, since tsunamis can be triggered by distant earthquakes and not just nearby ones, even the coastlines of countries with lower relative seismicity (for example, Ireland) carry some tsunami risk.

- Landslides are down-slope movements of rock, earth, mud, or debris that are commonly triggered by earthquakes, threatening human lives, destroying property, and blocking roads. The areas of Europe most susceptible to landslides are highlighted in Figure 2.

Impacts from past earthquakes

Between 2000 and 2020, it is estimated that earthquakes caused over €60 billion in direct damage within the EU Member States.[16] Notable recent events include the March 2020 M5.5 Zagreb earthquake and the December 2020 M6.2 Petrinja earthquake in Croatia, which caused an estimated €11 billion and €5 billion of damage and losses, respectively.[17] Since 2002, earthquake disasters in Italy have caused an estimated €47 billion in direct economic losses.[18] The EUSF has supported a proportion of costs since its establishment in 2022, as summarized in Table 1.

Over the past three decades, fatal earthquakes have occurred in Italy, Greece, Croatia, Spain, and Slovenia. Italy has experienced some of the deadliest earthquakes in the EU, including the 2016–17 Central Italy earthquakes, the 2012 Emilia-Romagna earthquakes, and the 2009 L'Aquila earthquakes, which collectively resulted in over 600 deaths and 1,800 injuries.[19] Earthquake fatalities are driven by the collapse of vulnerable buildings, such as unreinforced masonry or older, non-ductile concrete structures. These fatal earthquake events are highlighted in Table 2.

[13] Danciu et al. 2021.

[14] Bozzoni, F., R. Bonì, D. Conca, C. G. Lai, E. Zuccolo, and C. Meisina. 2021. "Megazonation of Earthquake-Induced Soil Liquefaction Hazard in Continental Europe." *Bulletin of Earthquake Engineering* 19 (10): 4059–82. Link.

[15] Basili, Roberto, Beatriz Brizuela, André Herrero, Sarfraz Iqbal, Stefano Lorito, Francesco Emanuele Maesano, Shane Murphy, et al. 2021. "The Making of the NEAM Tsunami Hazard Model 2018 (NEAMTHM18)." *Frontiers in Earth Science* 8. Link.

[16] This is a consensus statistic based on two sources: EU Solidarity Fund Interventions since 2002 (as of January 2025). Link., and EM-DAT, CRED/UCLouvain, 2024, Brussels, Belgium. Link.

[17] Based on direct damage declared in the applications for the EUSF assistance. Estimated losses vary depending on the source; for example, the estimates were €11.3 billion and €4.8 billion of damage and losses in the rapid damage and needs assessment: Government of Croatia. 2020. *The Croatia Earthquake - Rapid Damage and Needs Assessment 2020*. Government of Croatia. 2021. *Croatia December 2020 Earthquake - Rapid Damage and Needs Assessment*.

[18] Based on direct damage declared in the applications for the EU Solidarity Fund assistance.

[19] EM-DAT, CRED/UCLouvain, 2024, Brussels, Belgium. Link.

Figure 1. Spatial distribution of earthquake hazard

Source: Danciu, Laurentiu, Shyam Nandan, Celso G. Reyes, Roberto Basili, Graeme Weatherill, Céline Beauval, Andrea Rovida, et al. 2021. "The 2020 Update of the European Seismic Hazard Model: Model Overview." EFEHR Technical Report 001, v1.0.0. European Facilities of Earthquake Hazard and Risk (EFEHR). Link.
Notes: The figure shows expected ground shaking levels that have a 10 percent probability of being exceeded in 50 years, also known as the 475-year return period, which is a common design level across the EU. Colder colors indicate relatively lower hazard areas and warmer colors indicate relatively higher hazard areas (ESHM20).

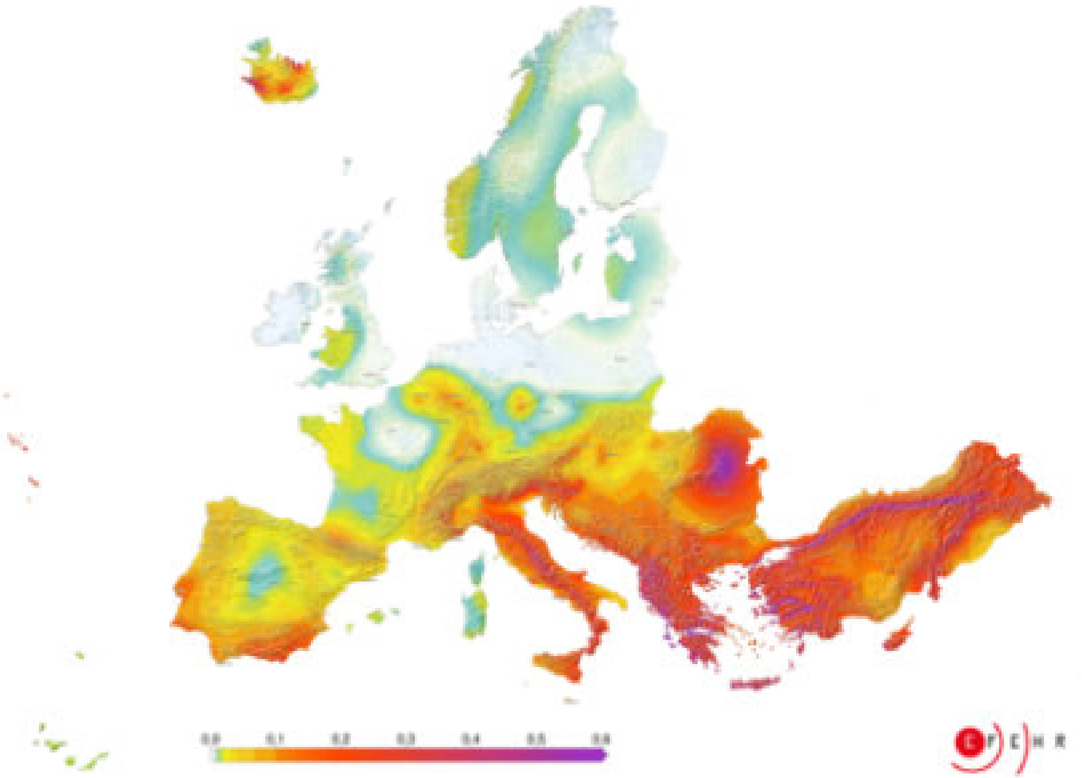

Figure 2. Spatial distribution of landslide susceptibility

Source: Wilde, M., A. Günther, P. Reichenbach, J.P. Malet, and J. Hervás. 2018. "Pan-European Landslide Susceptibility Mapping: ELSUS Version 2." Journal of Maps 14 (2): 97–104. Link.
Notes: Colder colors indicate relatively lower susceptibility areas and warmer colors indicate relatively higher susceptibility areas (ELSUS Version 2).

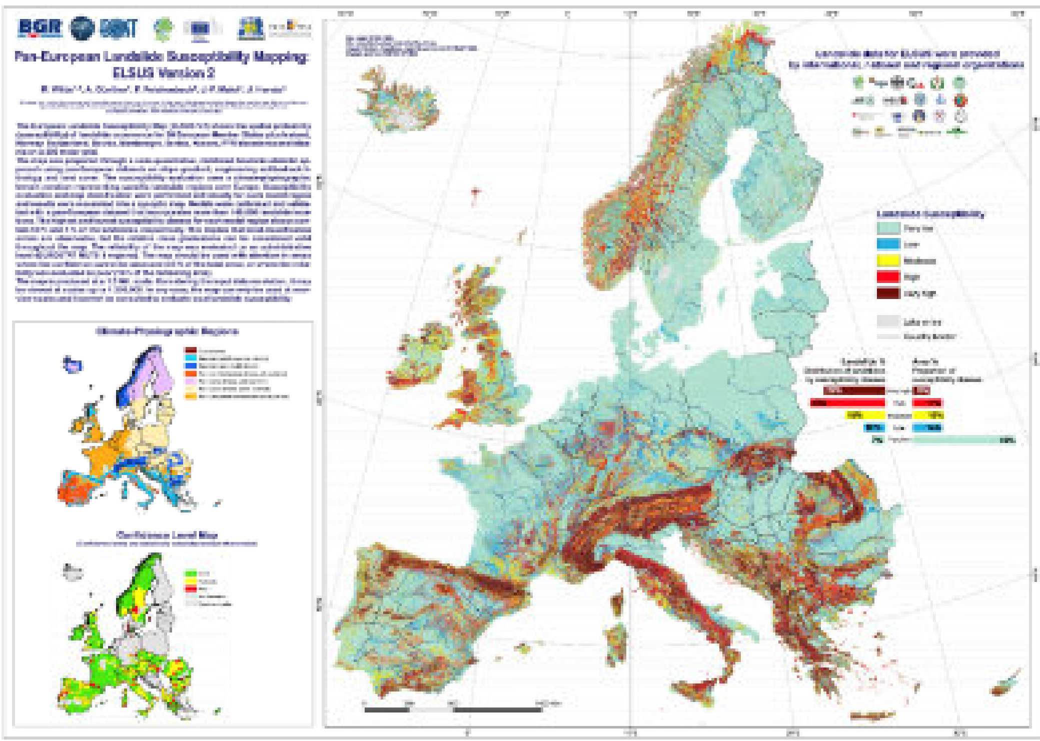

Table 1. Accepted applications for EUSF assistance for earthquakes since 2002

Source: Beneficiary States of the EU Solidarity Fund Interventions since 2002 (as of January 2025). Link.
Note: Sorted by EUSF monetary amount rewarded.

Beneficiary	Year	Area	Magnitude	Direct reported damage (€, million)	EUSF (€, million)	Percentage covered by EUSF
Italy	2016–17	Amatrice	6.2	21,879	1,197	5
Croatia	2020	Zagreb	5.4	11,573	684	6
Italy	2012	Emilia-Romagna	5.8	13,274	670	5
Italy	2009	Abruzzo (L'Aquila)	6.3	10,212	494	5
Croatia	2020	Petrinja	6.4	5,509	319	6
Italy	2002	Molise	5.9	1,558	31	2
Spain	2011	Lorca	5.1	843	21	3
Greece	2014	Kefalonia	6.9	147	4	3
Greece	2017	Kos	6.7	101	3	2
Greece	2020	Samos	7.0	101	3	2
Greece	2015	Lefkada	6.5	66	2	2
Greece	2017	Lesbos	6.3	54	1	3
Greece	2021	Crete	6.0	143	1	1

Table 2. Fatal earthquakes in EU Member States between 2000 and 2024

Source: EM-DAT, CRED / UCLouvain, 2024, Brussels, Belgium. Link. For Petrinja, Government of Croatia. Link.
Note: The listed earthquakes are those that caused at least one fatality and occurred between 2000 and 2024; sorted by the number of fatalities.

Country	Area	Magnitude	Year	Fatalities	Injuries
Italy	Central Italy	6.2	2016	296	400
Italy	Abruzzo (L'Aquila)	6.3	2009	295	1,000
Italy	Molise	5.9	2002	30	33
Italy	Central Italy	5.3	2017	29	11
Italy	Emilia-Romagna	5.8	2012	17	350
Spain	Lorca	5.1	2011	10	300
Croatia	Petrinja	6.4	2020	7	28
Italy	Emilia-Romagna	6.0	2012	7	50
Greece	Kefalonia	6.9	2014	3	2
Greece	Kos	6.7	2017	2	120
Greece	Samos	7.0	2020	2	19
Greece	Peloponnese	6.4	2008	2	240
Italy	Palermo	6.0	2002	2	Not reported
Italy	Ischia	4.3	2017	2	42
Croatia	Zagreb	5.4	2020	1	26
Greece	Lesbos	6.3	2017	1	11
Italy	Marche	6.1	2016	1	24
Greece	Crete	6.0	2021	1	20
Slovenia	Goriska	5.2	2004	1	5

Although recent earthquakes have had moderate magnitudes or were distant from heavily populated areas, there is precedent for catastrophic earthquakes within EU Member States. The most destructive of these historic earthquakes is the 1755 Great Lisbon earthquake that triggered damaging tsunamis and fires, killing between 40,000 and 50,000 people across Portugal, Morocco, and Spain. Another example includes the 1908 Messina earthquake in Italy (estimated magnitude 7.1) – one of the deadliest seismic events in Europe, which killed over 75,000. While such strong earthquakes are infrequent, their high consequences require consideration. Moreover, the impacts of such large earthquakes often extend beyond the borders of an individual country.

When earthquakes occur, damage to critical infrastructure and critical entities (e.g., education and health care facilities, police and fire stations, roads, power) can hamper emergency response and pose recovery challenges. Exposure analysis shows that over 30 percent of police stations and fire stations in the EU Member States are exposed to high seismic hazards (Figure 3).[20] These risks have also been observed in recent earthquakes, such as the 2016–2017 Central Italy earthquake sequence and the March 2020 Croatia earthquake, as described in Box 1. Although earthquakes pose significant risks to critical entities, data gaps and a limited understanding of risks to these systems and their interdependencies remain a challenge for effective risk reduction and preparedness.

Beyond the significant costs from both initial damage and repair works, earthquakes often result in long recovery times and permanent changes in affected areas. Earthquake-induced damage often takes years to decades to repair, during which households are displaced and access to essential services and infrastructure (for example, schools, health facilities, roads) is disrupted. For example, after the 2009 M6.3 earthquake in Italy, the L'Aquila city center was cordoned off and declared a restricted zone until 2014, and reconstruction continues over ten years later.[21] By December 2016, roughly 20 percent of the displaced population still had not returned home.[22] Earthquake damage and recovery needs often are not distributed uniformly across the population, and certain population subgroups may face disproportionate risks.

Future earthquake risk and risk drivers

The top 10 EU Member States predicted to have the highest relative seismic risk are Cyprus, Greece, Romania, Italy, Bulgaria, Croatia, Slovenia, Austria, Portugal, and the Slovak Republic.[23] Figure 4 highlights the local areas of Europe with the highest seismic risk according to recent scientific analyses, where cities such as Catania (Italy), Naples (Italy), Bucharest (Romania), and Athens (Greece) feature prominently. Other cities, including Zagreb (Croatia), Plovdiv (Bulgaria), Sofia (Bulgaria), Lisbon (Portugal), Limassol (Cyprus), Nicosia (Cyprus), and Rome (Italy) also feature above-average levels of seismic risk within the EU. Residential buildings account for over 50 percent of the average annual losses, yet household earthquake insurance penetration levels vary widely per country (from 0 to 97 percent), where the number of households insured for most countries is less than 25 percent.[24]

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[20] World Bank and European Commission. 2024.

[21] As of February 2024, 65 percent of the public works had been financed and over 98 percent of the dossiers for private construction instructed. See Landolfi, Flavia. "Fifteen years ago the L'Aquila earthquake. Where does the reconstruction stand? Superbonus capped at 70 million." *Il Sole 24 Ore*. Link.

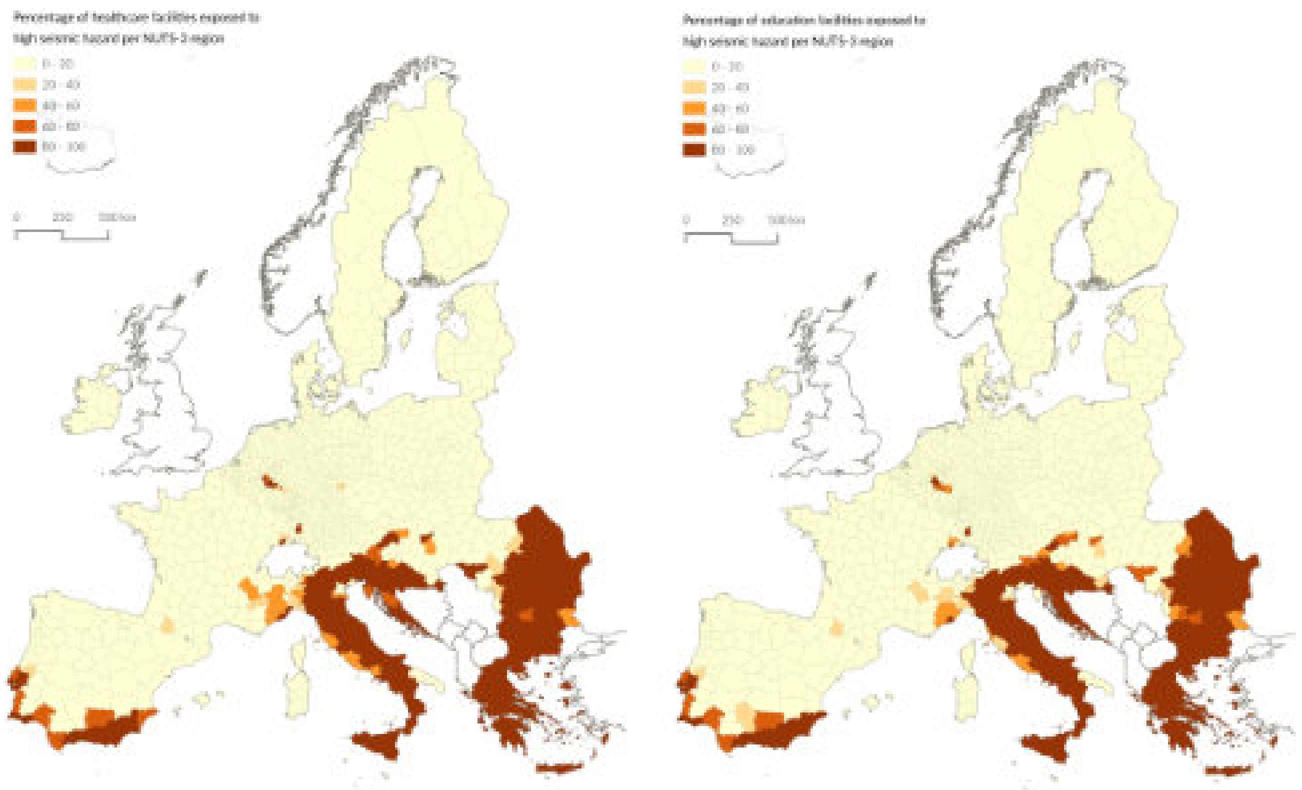
[22] Mannella, A., M. Di Ludovico, A. Sabino, A. Prota, M. Dolce, and G. Manfredi. 2017. "Analysis of the Population Assistance and Returning Home in the Reconstruction Process of the 2009 L'Aquila Earthquake." *Sustainability* 9 (8): 1395. Link.

[23] These predictions are based on catastrophe risk models covering the EU. The highest relative risk is defined here based on the average annual loss ratio for each country. Average annual loss ratios refer to the proportion of the building stock value that is expected to be damaged every year, on average, due to future earthquakes. The estimated average annual loss ratios are 0.19 percent for Cyprus, 0.18 percent for Greece, 0.12 percent for Romania, 0.11 percent for Italy, 0.07 percent for Bulgaria, 0.05 percent for Croatia, 0.04 percent for Slovenia, 0.02 percent for Austria, 0.02 percent for Portugal, and 0.01 percent for the Slovak Republic. World Bank. 2021a. Link.

[24] World Bank 2021a. For example, the proportion of households covered by earthquake insurance is 0 percent in Croatia, 7 percent in Italy, 7 percent in Cyprus, 10 percent in Bulgaria, 15 percent in Greece, 16 percent in Portugal, 20 percent in Romania, 25 percent in Slovenia, and 90 percent in the Slovak Republic.

Figure 3. Concentrations of exposure health care facilities (left) and education facilities (right) to high seismic hazard

Source: World Bank and European Commission. 2024. From Data to Decisions: Tools for Making Smart Investments in Prevention and Preparedness in Europe.



Box 1. Damage to critical entities during recent earthquakes in Croatia and Italy

Earthquakes pose significant risks to critical entities, hampering emergency response and disrupting essential services such as education and health care.

The March 2020 earthquake in Croatia damaged 46 health care centers, 125 hospitals and clinics, 20 medical institutes, and 23 pharmacies.[25] In the same earthquake, 513 educational buildings were also damaged. This physical damage disrupted medical services for over 1.4 million patients and education services for over 9,500 pupils and students, per estimates from the Ministry of Health and Ministry of Science and Education, respectively. Approximately 6,200 children were estimated to require relocation from damaged schools to new environments.

During the 2016–2017 Central Italy earthquake sequence, almost 50 percent of the 4,038 public and strategic buildings inspected were found unsafe, including 32 out of 80 buildings on hospital complexes.[26] Such damage levels become a life safety concern, especially considering the increase in seismic activity following a mainshock earthquake (that is, aftershocks).

[25] Government of the Republic of Croatia. 2020. *The Croatia Earthquake - Rapid Damage and Needs Assessment 2020*. Link.

[26] Di Bucci, D., M. Dolce, D. Bournas, D. Combescure, D. De Gregorio, L. Galbusera, M. Leone, et al. 2020. "Super Case Study 1: Earthquakes in Central Italy in 2016–2017." In *Science for Disaster Risk Management 2020: Acting Today, Protecting Tomorrow*, EUR 30183 EN, 201–2016. Luxembourg: Publications Office of the European Union. Link.

Seismic risk in Europe is primarily driven by existing buildings and infrastructure, which are extremely heterogeneous across the EU. A building stock inventory and vulnerability analysis across seismic-prone regions of Europe indicates that most buildings were either designed without any seismic design provisions or following only moderate-level seismic codes.[27] Mid-rise concrete frame buildings designed before modern seismic regulations and unreinforced masonry buildings contribute most to earthquake risks in Europe.[28] In Bucharest, Romania, nearly 90 percent of people inhabit multifamily buildings constructed before 2000 and are at relatively high risk of irreparable damage and collapse in earthquakes[29] Meanwhile, approximately 45 percent of all residential buildings in Croatia are unreinforced masonry, a construction type highly prone to collapse in earthquakes.[30] The vulnerability of this construction type has been witnessed in even more moderate earthquakes in the EU, such as the 2004 M4.9 Posočje earthquake in Slovenia and the 1983 Liège earthquake in Belgium, both of which saw damage to unreinforced masonry buildings. In recognition of the risk posed by older buildings, countries such as Italy and Romania have initiated seismic retrofit programs and incentives, sometimes combining seismic retrofit action with energy efficiency upgrades.

Although seismic hazard cannot be reduced within a given area, buildings and infrastructure can be designed or retrofitted to reduce damage and protect people. These approaches are informed by decades of research and lessons learned from past events, which are incorporated in Eurocode 8 (EN 1998 or EC8), a harmonized standard that guides the construction of earthquake-resistant structures in Europe. EU Member States have adopted EC8 since 2004 and are expected to implement it during new construction.

[27] Palermo, V., G. Tsionis, and M.L. Sousa. 2019. *Building Stock Inventory to Assess Seismic Vulnerability across Europe*. EUR 29257 EN. Luxembourg: Publications Office of the European Union. Link.

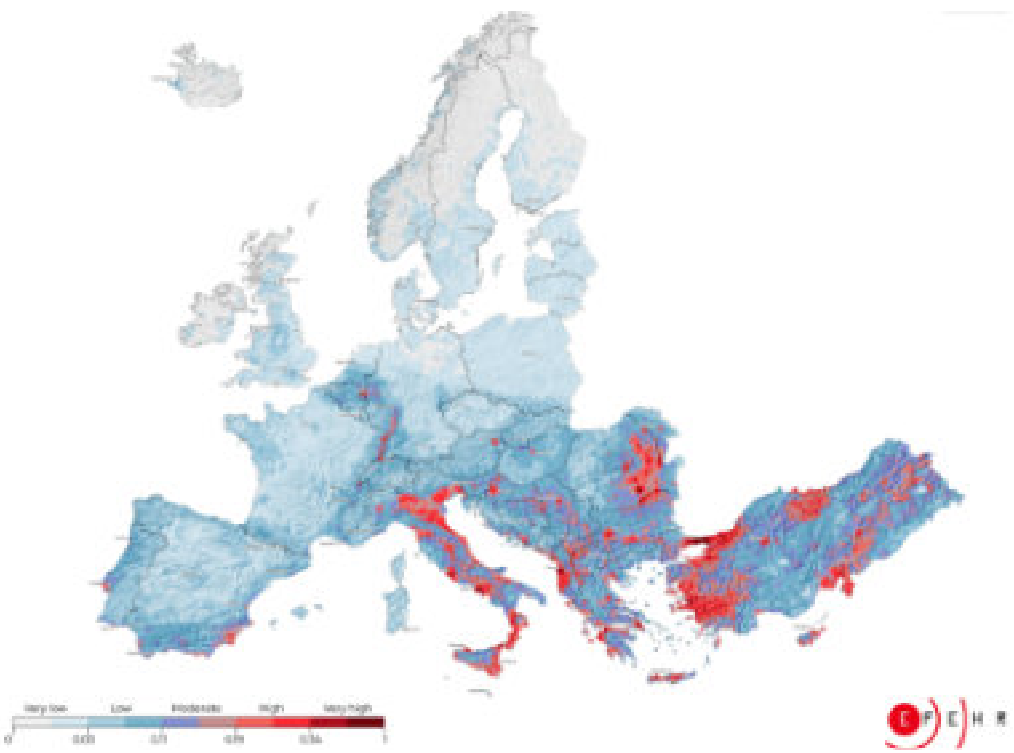
[28] Crowley et al. 2021.

[29] Simpson, A., and M. Markhvida. 2020. *Earthquake Risk in Multifamily Residential Buildings: Europe and Central Asia Region*. Washington, DC: World Bank. Link.

[30] Crowley, H., V. Silva, V. Despotaki, L. Martins, and J. Atalic. 2019. "European Seismic Risk Model 2020: Focus on Croatia." In *Future Trends in Civil Engineering*, 53–70. University of Zagreb Faculty of Civil Engineering. Link.

Figure 4. Spatial distribution of earthquake risk

Source: Crowley, H., J. Dabbeek, V. Despotaki, D. Rodrigues, L. Martins, V. Silva, X. Romão, N. Pereira, G. Weatherill, and L. Danciu. 2021. European Seismic Risk Model (ESRM20). IT: Eucentre. Link.
Notes: Blue colors indicate relatively lower risk areas and red colors indicate relatively higher risk areas (2020 European Seismic Risk Model [ESRM20]).



EARTHQUAKE RISK MANAGEMENT CAPACITY

The following chapters provide an overview of key gaps and vulnerabilities in existing earthquake risk management systems of relevance at the EU level, with examples of successful strategies, investments, and approaches. It draws on publicly available information such as national risk assessments, government reports, and studies as well as information gathered during consultations.

GOVERNANCE OF EARTHQUAKE RISK MANAGEMENT

This chapter focuses on disaster risk governance, which generally includes the legislative, institutional, strategic, and planning framework. The framework describes mandates, roles and responsibilities, as well as coordination arrangements among the different stakeholders, their policies, instruments, and investments. It is noted that EU Member States have different governance arrangements, which are also reflected in the way earthquake risk is managed, and this section does not cover in detail all such arrangements.

Current arrangements

Managing seismic risk in the EU is a multi-level effort, with primary responsibility lying with the Member States. The multi-level effort spans from commitment to global frameworks, such as the Sendai Framework for Disaster Risk Reduction, EU-wide cooperation, national strategies, and local implementation.

Within this governance framework, the EU complements, incentivises, and supports national efforts through a range of tools. The UCPM requires EU Member States and UCPM Participating States to conduct disaster risk assessments, provides emergency response assistance when earthquakes occur, and helps build collective preparedness for major disaster scenarios. The European Commission's Joint Research Centre (JRC) conducts seismic hazard and risk assessments, develops earthquake resilience tools, and provides scientific expertise to enhance earthquake risk management across the EU. Financial and technical support for national resilience efforts is provided through several EU instruments, including the cohesion policy funds, the Recovery and Resilience Facility, EU Solidarity Fund for post-disaster recovery, Horizon Europe for research and innovation, and the UCPM.

To strengthen situational awareness and seismic monitoring capacity, the EU works with external scientific organizations. For example, the European Commission's Emergency Response Coordination Centre (ERCC) cooperates with the European-Mediterranean Seismological Centre (EMSC) – an international nongovernmental organization that collects and disseminates real-time earthquake data from various seismological institutes.

An important part of the EU's contribution to earthquake risk management is the promotion of technical standards for earthquake-resistant construction – which is one of the most effective ways to reduce seismic risk. EC8, part of the broader Eurocode framework for structural design, sets the European standard for designing buildings and infrastructure to withstand seismic events. These standards are developed and maintained by the European Committee for Standardization (CEN), while the European Commission supports this work by issuing standardization requests, co-financing development, and promoting implementation as part of EU policy on safe and resilient infrastructure. The Eurocodes are adopted by each country separately through a process that involves translation into the national language and the creation of National Annexes that allow countries to adapt the codes to their local needs and regulatory environments. The JRC stores these Nationally Determined Parameters in a database, to which all EU Member States are registered.[31] EC8 was published in 2004, and EU Member States were expected to fully adopt and implement it by 2010. While not legally required by EU law, adoption is part of their commitment under the European standardization system. The EU supports capacity building for applying EC8, but national authorities are ultimately responsible for ensuring compliance. A second generation of the Eurocodes is currently being prepared, with final official language versions expected by 2026, followed by publication in 2027 and the withdrawal of the first generation of Eurocodes in 2028.

While the EU provides incentives, guidance and support, the overall approach to managing earthquake risk remains the responsibility of each Member State. National arrangements vary widely in terms of

[31] JRC. 2016. *Eurocodes Nationally Determined Parameters (NDPs) Database*. European Commission, [Dataset] PID. Link.

institutional, legal, and strategic frameworks. Despite these differences, a key good practice is the development of long-term, comprehensive strategies to ensure sustained action on preparedness and resilience. Several EU Member States (e.g., Italy, Romania) have taken coordinated, multi-sectoral, and multi-level approaches to address earthquake risks through dedicated national strategies and plans (Box 2). These documents identify key stakeholders (e.g., line ministries, local authorities, scientific institutions) and outline specific initiatives or programs to increase earthquake resilience (e.g., microzonation studies, seismic retrofit interventions and reconstruction, enhancing civil protection response capabilities, measures to increase public awareness and social inclusion, protection of cultural heritage) – supported by dedicated budgetary resources.

Box 2. Examples of national strategies and plans for earthquake risk reduction in the EU

Earthquake-specific national strategies and plans enable strategic long-term planning in earthquake risk reduction and facilitate coordination across the relevant stakeholders.

Romania's National Seismic Risk Reduction Strategy (NSRRS) from 2022 and its implementation plan aim to create a greener, more earthquake-resilient, and inclusive built environment by 2050 by (1) reducing seismic risk through targeted investments, (2) improving the sustainability and functionality of buildings, (3) integrating seismic risk into planning and recovery practices, and (4) increasing public awareness and participation. The NSRRS prioritizes seismic risk reduction in public and private buildings, including cultural heritage landmarks. Progress on the implementation of the strategy is monitored by the Ministry of Development, Public Works, and Administration (MDPWA), with all involved institutions reporting specific indicators to MDPWA in a standardized data collection and reporting approach. The MDPWA is also responsible for ensuring that the implementation of the NSRRS aligns with broader national strategies, with support from the Ministry of Internal Affairs and the General Inspectorate for Emergency Situations (GIES).

Italy's National Seismic Prevention Plan (NSPP)[32] was launched after the 2009 L'Aquila earthquake, with an aim to enhance seismic resilience across the country through a longer-term, programmatic approach to prevention. The Plan supports both structural and nonstructural measures, notably: (1) seismic microzonation studies and limit condition for emergency analyses; and (2) seismic retrofit interventions or reconstruction of public buildings, strategic infrastructure, and private buildings. The Plan is coordinated by the Department of Civil Protection, while regional administrations are responsible for implementation on the ground. It was initially backed by a dedicated fund of €965 million for the period 2010–2016.[33] Funding has since been extended beyond the original timeframe, with total allocations reaching over €1.7 billion for the 2010–2029 period.[34] Although investments made under the Plan are considerable compared to the past, the Civil Protection Department notes that they represent less than 1% of the resources needed to achieve full seismic upgrading of all public and private buildings and strategic infrastructure[35] - highlighting the vast scale of seismic risk and the long-term investment challenge.

[32] Decree n. 39/2009, converted into Law n. 77/2009.

[33] Dolce, Mauro, Elena Speranza, Giuseppina De Martino, Chiara Conte, and Francesco 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 (August): 102391. Link.

[34] Dipartimento della Protezione Civile. Year 2022 – 2023. Link.

[35] Dipartimento della Protezione Civile. 2009. National Plan for seismic risk prevention (art.11, Law no. 77-2009). Link.

Key challenges

While good practices exist, many EU Member States do not have earthquake-specific risk reduction plans or strategies, including countries that acknowledge seismic risks in their national risk assessments (NRAs) (for example, Austria, Bulgaria, Croatia, Portugal, the Slovak Republic). The absence of such frameworks can hinder the coherence of risk reduction efforts, complicate the clear allocation of responsibilities among key stakeholders, and make it more challenging to systematically track and monitor progress. For example, recognizing the importance of a strategic national approach, the 2019 UCPM Peer Review of Portugal's DRM system recommended the development of a National Seismic Risk Plan to account for the country's seismic hazard levels and the potential impact of a large earthquake.[36]

While national strategies and frameworks provide a crucial foundation for earthquake risk reduction, their effectiveness relies significantly on local-level implementation and capacity. Local governments play a key role in translating national policies into concrete actions, adapting them to local contexts, integrating risk information into urban planning, and ensuring community preparedness. Additionally, local governments are on the frontlines of emergency response, recovery, and reconstruction efforts. However, local-level authorities often lack access to risk information, adequate funding or technical capacity, and clear guidance on prioritization. A positive example of how local governments can be engaged in earthquake risk reduction activities is highlighted in Box 3.

Key opportunities

Developing earthquake-specific national risk reduction strategies, action plans, and/or investment programs can ensure more efficient earthquake risk prevention and reduction. Action plans and guidelines should clearly communicate the responsibility across different aspects of DRM at both the municipal and central levels. They can act as a collaboration mechanism that improves coordination and provides a framework for monitoring risk reduction efforts.

Creating roadmaps/action plans for local actions in high-risk areas and providing designated funding for local authorities can help scale up earthquake risk reduction. Tying national and EU funding streams to the creation of local earthquake mitigation plans can incentivize proactive risk reduction at the subnational level while helping to overcome common barriers such as limited financial and technical capacity. At the EU level, a funding stream to support the development of local earthquake risk reduction strategies—integrated with climate adaptation efforts—could be one avenue for scaling up earthquake risk reduction across EU Member States. Examples of such efforts to create roadmaps supporting local governments in taking proactive action to reduce earthquake risks in Greece and the United States are described in Box 4 and Box 5, respectively.

Opportunities exist to integrate seismic mitigation alongside national programs focused on climate mitigation, sustainability, and energy efficiency. While most EU countries have some measures related to energy upgrades, measures related to seismic upgrading or integrated upgrading remain limited. The latter include the Sismabonus tax incentive in Italy, legislation for the rehabilitation of existing buildings in Portugal, energy upgrading funding linked to verifying structural performance requirements in Bulgaria and Romania, and a 'building cards' instrument in Slovenia (see Figure 5).

At the EU level, scaling up earthquake risk reduction and ensuring lasting energy efficiency investments can be promoted through initiatives such as the Renovation Wave and New European Bauhaus. To support and promote integrated approaches for seismic strengthening and energy efficiency, the European Parliament initiated and the JRC implemented a pilot project REEBUILD ('Integrated techniques for the seismic strengthening and energy efficiency of existing buildings') in 2019.[37] The project defined technical solutions to simultaneously reduce seismic vulnerability and increase energy efficiency in Europe's aging building stock, providing a framework and practical tools to help stakeholders across Europe enhance safety and sustainability through integrated retrofitting approaches.

[36] Ecorys and Fraunhofer INT. 2019. *Peer Review Report: Portugal*. Link.

[37] Butenweg et al. 2022.

Box 3. Examples of proactive actions taken by a local government in Lisbon, Portugal

Local governments can take proactive actions to reduce earthquake risks.

Programa ReSist is a municipal program dedicated to promoting seismic resilience in Lisbon, Portugal. The program is implemented by a 12-person core team supported by technicians from a range of municipal services (for example, Municipal Directorate of Maintenance and Conservation, Municipal Directorate of Heritage Management, Department of Information Systems) and a technical-scientific council (for example, University of Aveiro, Portuguese Society of Seismic Engineering, Order of Architects). The program defined 47 specific measures to achieve the following objectives:

- Standardize technical standards and methodologies for assessing seismic vulnerability.
- Develop operational actions that effectively promote resilience via inspection campaigns, projects, and structural retrofit works.
- Conduct awareness and dissemination campaigns that empower both the general population (for example, the Lisbon Quake Museum, Treme-treme earthquake game for children) and key stakeholders (for example, architects, urban planners, civil engineers).
- Develop information management systems to streamline knowledge sharing and program execution between various municipal structures.
- Define strategic partnerships with external entities to optimize actions.

Source: Camara Municipal de Lisboa. Sismos: Programa ReSist. Link.

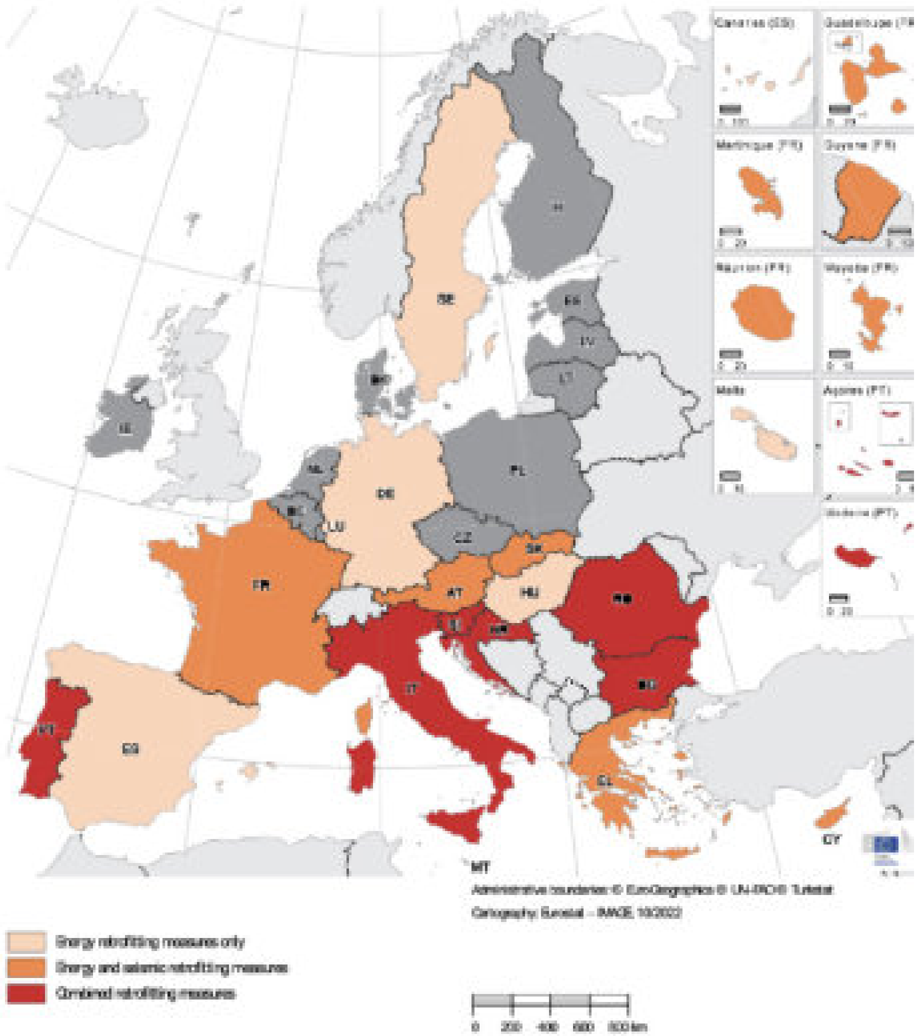


Figure 5. Existing building renovation measures identified for earthquake-prone countries

Source: Butenweg, C., H. Gervasio, K. Gkatzogias, V. Manfredi, A. Masi, D. Pohoryles, G. Tsionis, and R. Zaharieva. 2022. Policy Measures for Seismic and Energy Upgrading of Buildings in EU Member States. Luxembourg: Publications Office of the European Union. Link.

Note: Based on the REEBUILD Project where the considered countries are the 16 EU Member States that included seismic risk in their 2015 NRAs.

Box 4. Example of engaging and supporting local governments on earthquake risk reduction in Greece

National governments can support local governments in implementing earthquake risk management strategies by establishing clear funding mechanisms and providing guidance on prioritization of projects.

In Greece, the capacity for local development planning in disaster risk management usually relies on national and regional funding programs. 'Antonis Tritsis' is a Program for Solidarity and Development of Local Government, whereby the call 11 invited municipalities to submit proposals on earthquake protection works for public buildings.[38] The scope of the funding included: (1) a program of first-degree (rapid visual screening) or second-degree pre-seismic assessment of critical infrastructure (e.g., schools, sports facilities, water and sewage treatment facilities, town halls, monuments), and (2) a valuation study, redesign, and tender documents for the selected critical infrastructure (Call 11, 14578/24-07-2020). The original programming period was between 2020 and 2025, but was extended for another two years in 2023.

In Greece, the local government is typically responsible for the maintenance of schools and thus for mobilizing funding mechanisms and applying for programs to make structural modifications, upgrade, and retrofit the identified highly vulnerable public buildings. After completing the first-degree pre-seismic assessment (rapid visual screening) for all school buildings, the Municipality of Thessaloniki applied to receive funding from the state (under the Tritsis program) to (i) continue the first-degree assessment for the rest of the municipal buildings, and (ii) to conduct second-degree assessment for a smaller subset of the school buildings flagged during the first-degree assessment. The municipality's proposal also includes some funding for seismic reinforcement and energy upgrading of specific school buildings, as well as campaigns to raise citizens' awareness regarding how to act in case of a disaster. Moreover, the municipality applied and received funding from the National Strategic Reference Framework to conduct the appropriate seismic study of three school buildings that were identified as highly vulnerable, and then to retrofit and strengthen them according to the study.

Box 5. Example of an earthquake mitigation planning guide for local communities

National governments can support local governments in implementing earthquake risk management strategies by establishing clear funding mechanisms and providing guidance on prioritization of projects.

In 2024, the United States Federal Emergency Management Agency (FEMA) published an 'Earthquake Mitigation Planning Guide for Communities' that helps state, local, tribal, and territorial communities understand their earthquake risks and write corresponding mitigation plans linked to potential federal funding schemes.[39] The guidance document emphasizes a few important points about earthquakes, which are also relevant for Europe: (1) since earthquakes are one of the few natural hazards that strike with no warning, planning in advance is essential, (2) large earthquakes are infrequent and thus less politically popular than other hazards but pose significant risks that require consideration, and (3) relevant funding opportunities for mitigation may not explicitly reference earthquakes.

The strategic guidance in the document steps local communities through the hazard mitigation planning process: (1) organize the planning process (for example, secure technical expertise, define planning area, identify key stakeholders to join, allow the public opportunities to comment), (2) conduct a risk assessment (for example, identify the hazard, describe the hazard, identify and inventory community assets, analyze impacts, summarize vulnerability), (3) develop a mitigation strategy (for example, assess the community's capabilities and identify gaps, create a series of mitigation actions to address each identified hazard), and (4) adopt and implement the plan (for example, get approval of the plan from FEMA, treat the plan as a living document, update the plan every five years and after a major hazard event).

[38] A list of the AT11 projects can be found on the website: Link.
[39] FEMA. 2024. *Earthquake Mitigation Planning Guide for Communities*. US Department of Homeland Security. Link.


CAT

Current arrangements

This chapter focuses on the current understanding of earthquake risks in the EU, which is informed by various sources of data and analysis, research and innovation, national risk assessments, and subnational risk evaluations. Earthquake risk is understood as the combination of seismic hazard (for example, the frequency of earthquake occurrence, the strength of ground shaking given an earthquake), exposure (for example, the number of people exposed, the value of assets exposed), and vulnerability (for example, the susceptibility of assets to damage, the ability of populations to cope with earthquake effects).

Across the EU, earthquake-related data are collected through seismic networks and disaster damage and loss databases. The EMSC facilitates the rapid collection and dissemination of earthquake data and information. The seismic data are contributed by various seismological institutes (e.g., the Institute of Geophysics and Volcanology [INGV] in Italy) and through digitally crowdsourced data from earthquake witnesses.[40] The EU-wide data chiefly contribute to the collective understanding of seismic hazard. For seismic risk data, the European Commission Disaster Risk Management Knowledge Centre (DRMKC) Risk Data Hub includes a Losses and Damage Dashboard that presents disaster losses across Europe, including earthquakes.[41]

The EU funds research and innovation projects contributing to disaster risk reduction through programs such as Horizon Europe and UCPM budget (for example, Knowledge for Action in Prevention Preparedness, Disaster Risk Management Technical Assistance). For earthquakes, one of the key Horizon-funded projects for earthquakes was the SERA project, which developed the European seismic hazard and risk models.[42] This project supported the creation of two outputs: ESHM20 and ESRM20.[43] These scientific outputs have since been adopted across sectors to improve earthquake risk management, as described in Box 6. Another earthquake-related Horizon project is the Seismic Risk Assessment for Nuclear Safety (METIS), which is developing site-specific seismic hazard and risk methods for critical entities (that is, nuclear facilities).[44] There are also several Knowledge for Action in Prevention Preparedness projects addressing earthquake and earthquake-triggered hazards and risks. This includes, for example, BORIS2, which employs scenarios to investigate impacts on emergency management infrastructure in Italy, Austria, and Slovenia.[45]

In line with UCPM legal requirements, EU Member States regularly conduct NRAs, with earthquake risk included by those exposed to significant seismic hazard. In the 2023 reporting cycle, 15 EU Member States included earthquake risk in their NRAs: Austria, Bulgaria, Croatia, Cyprus, France, Germany, Greece, Hungary, Italy, Malta, the Netherlands, Portugal, Romania, Slovenia, and Spain. Additionally, nine Member States covered the tsunami risk: Cyprus, France, Greece, Ireland, Italy, Malta, Portugal, Romania, and Spain. Italy's NRA flags the high levels of damage caused by even moderate earthquakes due to the vulnerability of its building stock.[46] Cyprus's NRA echoes similar concerns regarding the vulnerability of its older building stock: roughly 17 percent of the country's buildings are masonry constructed before 1975, and 57 percent are concrete constructed before 1992, when seismic design codes were established on the island. These concerns are likely to be valid across the EU.

Some cities have also taken action to understand their seismic risks at more local levels. In addition to the Lisbon example mentioned above, Zagreb initiated an EU-funded project to assess earthquake risks in the city following the damaging 2020 earthquakes in Croatia.

[40] CSEM-EMSC. Link.
[41] European Commission. n.d. DRMKC-Risk Data Hub. Link.
[42] SERA. Link.
[43] EFEHR. 2022. "Press Release: New Earthquake Assessments Available to Strengthen Preparedness in Europe." Link.
[44] METIS. Seismic Risk Assessment for Nuclear Safety. A Horizon 2020 Project. Link.
[45] BORIS2 (Cross Border Risk Assessment for Increased Prevention and Preparedness in Europe). Link.
[46] Italian Civil Protection Department. 2018. *National Risk Assessment*.

The three-year project aimed to define seismic hazards for the City of Zagreb, develop a methodology for seismic risk assessment that would also apply to other major cities in Croatia, create a database of buildings and population, conduct a seismic risk assessment, and organize consultations and professional conferences. The data have been provided to emergency services and civil protection to more effectively prepare for and respond to future earthquakes and facilitate the development of measures for rapid recovery in earthquake-affected communities.

Key challenges

Earthquake risk information can be better integrated into land use planning. While scientific institutes have advanced the understanding of earthquake hazard and risks (for example, through microzonation studies), integration of this knowledge within spatial planning remains a challenge. This lack of integration may stem from gaps in legislation, weak enforcement of existing regulations, or limited access to relevant data or risk information needed for planning. Moreover, without dedicated programs and associated funding, it is difficult to prioritize seismic risk reduction measures unless they can be easily integrated with other synergistic initiatives (for example, energy efficiency upgrades, urban upgrading, broader redevelopment).

Box 6. Use of scientific data from ESHM20 and ESRM20

EU funding for research and innovation contributes to state-of-the-art scientific outputs that increase understanding of earthquake risks, while open access ensures that outputs can be applied across a range of sectors to strengthen earthquake risk management.

The ESHM20 and ESRM20 projects were a significant multi-institutional effort to derive a harmonized view of seismic hazard and risk in Europe. This included developing multiple scientific products, which have been openly published (for example, a unified earthquake catalogue, database of active faults, vulnerability models). This scientific information has since been used across sectors and in different aspects of the disaster risk management cycle:

- The ESHM20 hazard map is to be published in the upcoming second generation of EC8, while several countries (for example, Greece, Slovenia) are using model components to inform the national hazard models underpinning their NRAs and National Annexes.
- The seismic hazard levels and seismic design code levels from ESHM20 and ESRM20 were used to inform a JRC study identifying the European buildings that would most benefit from seismic and energy upgrades in Italy.[47]
- The 2020 European Fault-Source Model from ESHM20 was used to inform lifeline crossing locations in a methodology proposed and adopted in an informative annex of Eurocode 3 (PrEN 1998-4:2022).[48]
- The model inputs and outputs of ESHM20 and ESRM20 have been integrated into catastrophe risk models that inform insurance pricing or are used to validate and cross-check alternative models.
- The seismic hazard and risk models from ESHM20 and ESRM20 have been incorporated in the Global Seismic Hazard and Risk Models published by the Global Earthquake Model Foundation, which support risk-informed decision-making by public and private sector entities and the general public.

[47] Romano, E., P. Negro, G. Santarsiero, A. Masi, and C. Butenweg. 2023. "Identification of European Buildings Most Needing Seismic and Energy Retrofit with a Focus on the Italian Context." Link.

[48] Melissianos, V., D. Vamvatsikos, L. Danciu, and R. Basili. 2024. "Design Displacement for Lifelines at Fault Crossings: The Code-Based Approach for Europe." *Bulletin of Earthquake Engineering* 22 (5): 2677–2720. Link.

Existing loss and damage data related to earthquakes in the EU are coarse and inconsistent, resulting in large uncertainty and limiting understanding of seismic risks. While some databases of earthquake damage and loss exist and cover the EU, reported impacts vary significantly between sources, and the compiled data lack detail. More detailed loss and damage data are often collected within individual countries or by insurers but are rarely made accessible to the public or reported to update larger databases. The data could greatly aid the development of better risk assessment models and enhance our understanding of vulnerabilities and the scale of potential future impacts.

Earthquakes can trigger aftershocks and a variety of secondary perils – ground shaking, liquefaction, and landslides. These are typically not included in risk models, which limits a holistic understanding of earthquake risks. Aftershocks and secondary perils can be as damaging as ground shaking from the mainshock or more and can cause cumulative damage. For aftershocks, there is a movement toward time-dependent models, which account for how earthquake risks evolve over time, including the likelihood and impact of aftershocks.[49] For secondary perils, a key milestone was the establishment of the Global Tsunami Model (GTM) in September 2024.[50]

Critical entities and infrastructure play a key role in societal functions and can be vulnerable to earthquake damage and disruption, but less is known about these risks.[51] According to the Critical Entities Resilience Directive (EU 2022/2557, CER Directive), critical entity sectors include energy, transport, banking, financial market infrastructure, health, drinking water, wastewater, digital infrastructure, public administration, space, and production, processing, and distribution of food. Across these sectors, only a limited number of studies investigate earthquake risks. In general, earthquake risks to critical infrastructure and infrastructure networks are anticipated to be higher in southeastern Europe, where the seismic hazard is higher. However, there is limited detailed data or understanding of the vulnerability of this infrastructure to earthquake effects, which inhibits prioritization of mitigation measures. For example, including earthquake and tsunami risk in the risk management planning of Portuguese port facilities and other critical infrastructure was one of the recommendations made in the 2019 UCPM peer review of disaster risk management in Portugal.[52] An additional challenge lies in the complex dependencies of critical infrastructure, where failures can cascade across networks, causing significant direct and indirect consequences. Systemic risk analyses are required to quantify these cascading impacts, yet few such analyses exist.[53]

Current estimates of earthquake risks are aggregate economic losses and fatalities, with much less known about which population subgroups might face disproportionate risks. Evidence from past disasters consistently shows that poor and marginalized groups tend to be most affected by disasters.[54] Social vulnerability factors might include gender, age, income level, housing tenure, language, and immigration status. In recognition of this, a social vulnerability lens has often been applied to disaster research to reflect how social inequalities shape various groups' susceptibility to harm and ability to respond or cope with disasters.[55] Despite this, models used to quantify earthquake risks rarely incorporate social vulnerability or estimate disaggregated losses.[56] Therefore, the understanding of which demographic groups face disproportionate earthquake risk and recovery challenges is limited.

[49] Lacoletti, S., G. Cremen, and C. Galasso. 2024. "Investigating the Sensitivity of Losses to Time-Dependent Components of Seismic Risk Modeling." *Earthquake Spectra* 40 (2): 1376–95. Link.

[50] Global tsunami model (GTM). Link.

[51] UNDRR. 2021. *Addressing the Infrastructure Failure Data Gap: A Governance Challenge*. Link.

[52] Ecorys and Fraunhofer INT 2019. *Peer Review Report: Portugal*. Link.

[53] Verschuur, J., R. Pant, E. Koks, and J. Hall. 2022. "A Systemic Risk Framework to Improve the Resilience of Port and Supply-Chain Networks to Natural Hazards." *Maritime Economics & Logistics* 24 (3): 489–506. Link.

[54] Hallegatte, S., A. Vogt-Schilb, J. Rozenberg, M. Bangalore, and C. Beaudet. 2020. "From Poverty to Disaster and Back: A Review of the Literature." *Economics of Disasters and Climate Change* 4 (1): 223–47. Link.

[55] Blaikie, P., T. Cannon, I. Davis, and B. Wisner. 2014. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd ed. London: Routledge. Link.

[56] Soden, R., D. Lallemant, M. Kalirai, C. Liu, D. Wagenaar, and S. Jit. 2023. "The Importance of Accounting for Equity in Disaster Risk Models." *Communications Earth & Environment* 4. Link.

Key opportunities

Cities and municipalities can take action to understand seismic hazards and risks through seismic microzonation studies. Microzonation studies involve geological and geotechnical surveys and analysis, which are used to create detailed maps of seismic hazards in an area. This information can be incorporated into building codes, inform territory and land use management, and guide post-earthquake reconstruction. Inspiration can be drawn from Italy where seismic microzonation studies are one component of NSPP, with thousands of such studies having been conducted in collaboration with national and local civil protection organizations, regional and municipal administrations, and the scientific and professional communities.[57]

National and local authorities can also improve their understanding of seismic risks through building inventories, which can also inform prioritization of retrofitting efforts. Reliable building inventory data are crucial in understanding earthquake risks at local levels: information on building age, primary construction material, and the number of stories is critical to assessing buildings' vulnerability to earthquake ground shaking. While such information may exist across agencies and cadaster databases, it should be made accessible and complete for earthquake-related assessments. In Bucharest, Romania, a research project created an online building database by combining two existent databases: the database of technically surveyed buildings and the land book registry.[46] For a test area limited to a part of the historical city center, this database combined existent seismic risk information with cadastral information in order to improve the level of knowledge on the buildings therein. Expanding this approach – by integrating additional data on energy efficiency –, could inform risk reduction plans that simultaneously address energy performance and seismic safety. Beyond informing building upgrade programs, an inventory of vulnerable buildings increases public awareness and can inform emergency planning (e.g., ensuring critical evacuation routes are not interrupted by the collapse of these buildings).

There is an opportunity for improved accessibility of seismic risk information and standardization of damage and loss data. Recent efforts to collect damage and loss data, such as the European Commission DRMKC Risk Data Hub,[58] are promising. However, they would ideally be linked to national systems (for example, IMSES in Romania) and feature standardized loss reporting in future events and verification for past events. Where possible, including aggregate insurance loss data would also be useful. The accessibility of NRAs is limited—some are public, but not all—limiting public awareness of such risks.

Additional research can improve understanding of secondary perils triggered by earthquakes, such as tsunamis, landslides, liquefaction, and fire following. Additional effort is required to quantify hazard, vulnerability, and risk for these secondary perils, similar to what has been performed already for earthquake ground shaking. One promising initiative related to tsunamis is the recent establishment of the GTM Foundation as a legal entity, which is described further in Box 7.

Data collection and systemic risk assessment for critical entities are required to advance global and European aims, including Target D of the Sendai Framework for Disaster Risk Reduction 2015–2030 and the EU's CER Directive. Systematized data collection for critical entities and infrastructure is required to fill existing data gaps and support risk analyses, including those required by the CER Directive. Such a process might include mapping infrastructure assets (for example, location, network structure), quantifying dependencies (for example, type, importance, strength), quantifying services (for example, number of end users, service area), and recording damage and disruptions from past events.[59] This information could feed into systemic modeling approaches that quantify direct and indirect consequences.

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57 Dolce, M., F. Bramerini, S. Castenetto, and G. Naso. 2019. "The Italian Policy for Seismic Microzonation." In *Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions*. CRC Press.

58 European Commission. DRMKC. Link.

59 Schotten, R., E. Mühlhofer, G. Chatzistefanou, D. Bachmann, A. Chen, and E. Koks. 2024. "Data for Critical Infrastructure Network Modelling of Natural Hazard Impacts: Needs and Influence on Model Characteristics." *Resilient Cities and Structures* 3 (1): 55–65. Link.

Box 7. Example of an ongoing initiative to understand secondary perils from earthquakes: tsunamis

Promising initiatives to advance understanding of secondary perils triggered by earthquakes exist, and continued investment and support of these initiatives will enhance a more holistic understanding of earthquake risks.

The GTMFoundation, formally established in September 2024, is an international scientific consortium dedicated to improving global understanding of tsunami hazard, especially tsunamis triggered by earthquakes. Originating as a collaborative network in 2016, GTM Foundation brings together experts and scientific institutions from across Europe and beyond to support research, education, and outreach on tsunami risk. One of the GTM Foundation's flagship initiatives is the update of the global Probabilistic Tsunami Hazard Assessment for earthquake-generated tsunamis. This work will refine the 2018 global risk model. [60]

[60] Davies, G., J. Griffin, F. Løvholt, S. Glimsdal, C. Harbitz, H. K. Thio, and M. A. Baptista. 2018. "A Global Probabilistic Tsunami Hazard Assessment from Earthquake Sources." Link.

EARTHQUAKE RISK PREVENTION, REDUCTION, AND MITIGATION

This chapter focuses on earthquake risk prevention, reduction, and mitigation. Earthquakes occur with minimal warning times, which limits the ability to remove people and property in advance; therefore, most earthquake risk reduction efforts focus on mitigation by reducing exposure and vulnerability. This includes the development and enforcement of building codes with earthquake-resistant design requirements, land use planning to consider high-risk areas near faults or unstable soil and retrofitting existing buildings and infrastructure.

Current arrangements

Earthquake risks are reduced by constructing new structures to modern seismic-resistant design standards, such as EC8. EC8 is adopted across the EU, but its level of implementation varies among EU Member States. EC8 is currently undergoing a major update that will be published in September 2027. Among the key changes are a new approach to defining the earthquake forces that structures must be designed to withstand and the introduction of a common set of European seismic hazard maps based on the latest scientific data from the ESHM20 model developed by the SERA project. These maps will be included in an annex to the standard, but each country will still decide whether and how to use them.

Targeted retrofit programs are required to reduce the risk in existing buildings, which are the main driver of seismic risk in the EU. Seismic retrofit programs typically involve multiple phases: initial rapid visual screening and prioritization, engineering assessment and calculations, then detailed assessment and design for implementation. Seismic retrofit can also be done in combination with energy efficiency, accessibility, fire safety, and other functional improvements. In the EU, seismic retrofit programs have largely focused on reducing risks to public buildings and critical infrastructure. For example, the Italian NSPP after the 2009 L'Aquila earthquake included a measure on the seismic retrofit of strategic or critical buildings and infrastructure whose damage could affect emergency management or lead to significant loss of life. Other examples of retrofit programs undertaken in the EU are summarized in Box 8.

Key challenges

The key challenge Europe faces with respect to earthquake risk reduction is the vulnerability of existing buildings and infrastructure. Most buildings in Europe were either designed without any seismic design provisions or following only moderate-level seismic codes.[61] These buildings face the greatest risk of destruction and collapse. Historic centers with older concrete buildings and unreinforced masonry are at particular risk. For example, damage in the March 2020 Croatia earthquake primarily affected historic buildings in Zagreb's historic city center, with the most substantial damage sustained in buildings built between 1880 and the mid-twentieth century.[62] Meanwhile, a study found that nearly 90 percent of people in Bucharest, Romania, reside in multifamily buildings constructed before 2000 and are at relatively high risk of irreparable damage and collapse in earthquakes.[63]

Preserving cultural heritage in earthquakes is important, but can pose both a technical and administrative challenge. Historic buildings are often vulnerable to even moderate earthquakes, and damage to these structures can result in significant social and economic impact. However, these structures are also complex and difficult to assess without qualified visual inspection or advanced assessment techniques. Further, there are often stricter requirements for cultural heritage structures that require seismic safety concerns to be balanced with the maintenance of architectural and artistic features of these structures.[64]

[61] Palermo, V., G. Tsionis, and M. L. Sousa. 2019. *Building Stock Inventory to Assess Seismic Vulnerability across Europe*. EUR 29257 EN. Luxembourg: Publications Office of the European Union. Link.

[62] Government of the Republic of Croatia 2020.

[63] Simpson and Markhvida 2020.

[64] Spyrakos, Constantine C. 2018. "Bridging Performance Based Seismic Design with Restricted Interventions on Cultural Heritage Structures." *Engineering Structures* 160 (April): 34–43. Link.

Box 8. Examples of integrated critical entity retrofit programs in Romania

Some EU Member States, such as Romania, have taken steps to enhance their earthquake resilience through seismic retrofit programs, addressing critical entities such as emergency response units and education facilities.

Romania's NSRRS integrates public and private sector efforts to address seismic vulnerabilities through a tiered evaluation methodology that prioritizes high-risk buildings for efficient fund allocation. The MDPWA leads the implementation of Romania's seismic risk reduction strategy, with its national program and World Bank-funded projects complementing each other to focus on high-risk buildings, emergency response infrastructure, and schools. Together, these initiatives create a cohesive framework aimed at enhancing Romania's resilience to seismic events, with a strong emphasis on public safety, sustainability, and energy efficiency.

State-Led Seismic Risk Reduction Efforts in Romania: The MDPWA leads the National Program for the Consolidation of Buildings with High Seismic Risk 2023-2026, a €2.4 billion initiative co-funded by the EU and aimed at improving seismic safety and energy efficiency in residential and public buildings.[156] The program follows the BBB principle, focusing on demolishing and replacing non-historic, seismically vulnerable buildings with safer, energy-efficient structures. The Residential Buildings Subprogram is funding seismic retrofit and energy improvements for 73 residential and 100 public buildings between 2024 and 2027. In parallel, the Public Interest Buildings Subprogram focuses on seismic upgrades and energy improvements for schools (214 in 2025, with more added annually) and hospitals (34 in 2024, with additional facilities each year), alongside technical assessments for 4,800 buildings by 2027 to support future prioritization and investment.

Complementary World Bank-Funded Projects: The World Bank is supporting Romania's seismic risk reduction efforts with over €330 million in projects targeting critical infrastructure like emergency assets (police, fire, and gendarmerie facilities) and schools, designed to complement the state-led strategy. These projects are implemented by the General Inspectorate of Emergency Situations (under the Ministry of Internal Affairs) and include the Strengthening Disaster Risk Management Project (2018–2027), the Improving Resilience and Emergency Response Project (2019–2025), and the Strengthening Preparedness and Critical Emergency Infrastructure Project (2019–2025). Not only will the retrofitted or reconstructed fire stations and emergency service centers be more disaster resilient, but they will also be energy efficient and universally accessible. By 2027, 35 facilities serving 25 percent of Romania's population will be renovated and ensure the safety of around 1,000 firefighters and paramedics. Additionally, retrofitting education facilities is a priority, with the Safer, Inclusive, and Sustainable Schools Project (2021–2027) aiming to retrofit 55 schools in high seismic areas, enhancing resilience, energy efficiency, earthquake resistance, fire safety, accessibility, and creating modern, inclusive spaces for students, including those with disabilities and from marginalized communities.

[156] Government of Romania, Ministry of Investment and European Project. National Program for Strengthening Buildings with High Seismic Risk (PNCCRS) [*Programul național de consolidare a clădirilor cu risc seismic ridicat (PNCCRS)*]. Link.

Addressing earthquake risk requires large-scale retrofitting efforts, yet constrained public budgets and limited dedicated funding remain significant barriers to effective risk reduction. This challenge is exacerbated by the limited use of investment prioritization frameworks, which are critical to allocate limited funding effectively and address the most vulnerable structures first. Since large earthquakes are infrequent, earthquake risk prevention and reduction programs are often not prioritized until a damaging event occurs. However, once such an event occurs, local and national governments struggle to balance the immediate costs and desire to return to normal as soon as possible with BBB approaches that might reduce risks in future earthquakes. While the post-disaster period offers a unique window of opportunity with heightened awareness to improve construction practices for seismic resistance, programs targeting seismic retrofit of high-risk buildings would ideally take place before the occurrence of a damaging event.

A lack of a unified approach to tiered screening and assessment of existing buildings in the EU hinders the scaling up of retrofit programs. Existing structures are the primary driver of earthquake risk in the EU, but are often complex as subsequent additions or renovations may have created new structural deficiencies (for example, removal of a load-bearing wall to create open space). Since retrofitting all existing buildings is infeasible, tiered approaches to screening and assessment are essential for prioritization. These tiers increase in detail and effort, with quicker approaches being more conservative and more detailed approaches requiring greater resources and being more appropriate for smaller portfolios, as summarized in Table 3. Notably, EC8 Part 3 provides guidance for a detailed assessment of existing buildings, but not for rapid visual screening and initial assessment. In past retrofit programs in the EU, international standards have often been used instead, which do not always align with the seismic hazard levels and performance objectives of EC8. While some countries like Greece have developed their own tiered assessment approaches (see Box 9), in the absence of unified assessment guidance, ad hoc approaches have been undertaken by individual countries and on individual retrofit programs.

Table 3. Multi-tier approach to seismic safety assessment of buildings

Source: Based on consultations and public information.

	Rapid visual screening	Initial assessment	Detailed assessment
Description	Rapid visual screening typically involves on-site or virtual inspection, with a basic scoring system that considers building age, construction type, and several factors related to structural deficiencies. These approaches do not require calculations.	An initial assessment may involve checking for common structural deficiencies, which are known to create life safety issues in earthquakes. These assessments involve reviewing structural drawings and performing simplified calculations.	A detailed assessment is critical to informing retrofit design and implementation and is typically performed in conjunction with retrofit design. Beyond the steps listed in the initial assessment, this often includes modeling individual buildings and using structural engineering software to conduct seismic analysis.
Candidate portfolio size (number of buildings)	>100	<100	<10
Effort per building	Minutes to hours	Days to weeks	Weeks to months
Codes and standards (origin)	FEMA P-154 (US)	ASCE41 Tier 1 or 2 (US)	Eurocode 8 Part 3 (Europe) ASCE41 Tier 3 (US)

While retrofit programs for public buildings and infrastructure are under way across several EU countries, they are typically not part of an overarching earthquake risk reduction strategy or large energy efficiency programs. Increasing earthquake resilience requires that planning and prioritization frameworks be applied systematically across all critical sectors (for example, emergency response, education, health care, transportation, energy). However, retrofit programs are typically undertaken by individual ministries or departments, with limited cross-sectoral knowledge and technical expertise sharing. In addition, the implementation of national programs can be hindered by the lack of technical capacity at the local level to implement assessment, prioritization, and retrofit planning efforts. For example, some municipalities in Greece, namely those with the lowest population, often lack the personnel and technical knowledge to apply for national funding for the seismic assessment and prioritization of schools under their responsibility and face challenges in increasing the capacity. In addition, given that earthquakes are not a climate risk, they are typically not addressed by large climate and energy efficiency investment programs.

Seismic retrofit programs have occasionally targeted private buildings, but uptake has been low. For example, Romania initiated a National Seismic Assessment and Rehabilitation Program for existing buildings in 1992, where the government fully funded seismic assessment that resulted in a list of vulnerable buildings' 'urgency categories'.[65] Building owners were responsible for retrofit costs, but the government offered a no-interest loan to incentivize retrofit. By 2013, an important number (over 2000) of buildings were assessed, but few had performed retrofit work.[66] Reasons for low uptake include difficulties in reaching consensus across multiple owners within apartment buildings, a reluctance of occupants to move into temporary accommodations, and high retrofit costs.[67] More generally, private investment in seismic risk reduction needs to be stimulated by public risk awareness and sufficiently attractive incentive structures such as tax incentives, lower insurance premiums, or the ability to generate additional income through, for example, adding floors.

[65] Between 1992 and 1997, Romania conducted an en masse seismic risk assessment effort, which ranked vulnerable buildings in Urgency categories: U1, U2, or U3. The urgency category of a building represented its prioritisation for retrofitting, based on its seismic risk, with U1 buildings needing to be retrofitted in maximum 2 years, U2 in maximum 5 years and U3 in maximum 10 years.

[66] Zhang, Y., J. Fung, K. Johnson, and S. Sattar. 2022. "Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States." *Journal of Earthquake Engineering* 26 (12): 6208–35. Link.

[67] Craifaleanu, I. 2013. "Eurocode 8, Part 3 and the Romanian Seismic Code for the Assessment of Existing Buildings, P100-3: Similarities and Differences." Link.

Box 9. Phased approach to screening and assessment of existing buildings in Greece

Some EU Member States, such as Greece, have developed their own phased approaches to screen and assess the vulnerability of existing buildings, helping them to prioritize seismic retrofit across a large portfolio of buildings.

The Earthquake Planning and Protection Organization (EPPO)[68] in Greece has developed a standardized approach to tiered screening and assessment of existing buildings. The EPPO, founded in 1983, is a legal entity under Public Law and is supervised by the Ministry of Climate Crisis and Civil Protection. Its purpose is to elaborate and plan the country's seismic policy within the framework of government guidelines as well as to coordinate the actions of public and private resources for the implementation of this policy. The approach for the seismic assessment of existing buildings developed by EPPO includes three stages:

- **First-order** pre-seismic assessment, a rapid visual screening method, which is a simplified method based on FEMA 154 (ATC-21)[69] that can be applied to many buildings as described in Table 2. This method results in a score depending on a variety of easily observable parameters. Buildings having a structural score equal to or below a prescribed limit should be investigated in more detail, while those with a score above this limit are considered sufficiently seismically safe. In 2024, this method was updated to consider more advanced grading on the parameters.

- **Second-order** pre-seismic assessment, which is applied to the buildings that need further investigation as the result of the first-order assessment. This is an approximate assessment of the seismic capacity of the building based on simplified hand calculations and non-destructive checks.

- **Third-order** pre-seismic assessment, which is required for the buildings that prove vulnerable according to the second-order pre-seismic assessment. This is an analytical assessment of the seismic capacity of the building according to the current assessment and intervention regulations (for example, EC8 - Part 3). In this case, a comprehensive study is conducted to design retrofitting strategies to strengthen them.

Box 10. Example of a private retrofit program and incentive in Italy

There is evidence that private building owners will respond to incentives to seismically retrofit their buildings in Europe.

In 2017, the Italian High Council of Public Works introduced a tax incentive called the 'Sismabonus' to motivate building owners to strengthen their buildings. This bonus offers a tax reimbursement of up to 85 percent of the retrofit cost for structural and nonstructural components, depending on the type of dwelling and the level of improvement.[70] The total reimbursement cannot exceed €96,000 for each real estate unit.

Through a separate scheme called 'Ecobonus", building owners are encouraged to improve energy efficiency. While the two policies were not initially integrated, a 'Superbonus' was later introduced to combine the benefits of both seismic and energy efficiency upgrades and to stimulate the construction sector during the COVID-19 pandemic. Initially, the 'Superbonus' covered up to 110 percent of the renovation costs, which had such broad appeal that actual costs far exceeded budgetary plans. Due to the popularity of the program with voters and small businesses, the government has since extended the 'Superbonus' with a lower percentage of the expenses covered. The 'Superbonus' is also attributed to helping Italy perform better than any other major European economy since the COVID-19 pandemic, with a 31 percent increase in construction output in four years to the end of 2023. This case shows that private building owners can indeed be incentivized to retrofit and upgrade their buildings.[71]

[68] Government of the Republic of Greece. Ministry of Climate Crisis and Civil Protection. Link.

[69] FEMA. 1988. *FEMA 154 (ATC-21): Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook.* Applied Technological Council (ATC), Washington, DC, USA.

[70] Ibid.

[71] Reuters. 2024. "Why Italy's Superbonus Blew a Hole in State Accounts." Link.

Key opportunities

Programs for seismic retrofit of public buildings and infrastructure need to be accelerated in more countries, especially for critical entities and infrastructure. The 2022 Critical Entities Resilience Directive (EU Directive 2022/2557 or CER Directive) further strengthens the case for action by requiring Member States and designated critical entities to assess and address all relevant risks, including earthquakes, to ensure the continuity of essential services. Investing in seismic retrofitting is not only vital for safety—it also has been proven to be cost-effective. In Italy, such investments have shown benefit-cost ratios from 1.59 to 3.29, when considering avoided casualties, damage, and disruptions in future earthquakes.[72]

Unified guidelines for rapid visual screening and tiered seismic assessment across the EU could improve the efficiency of identifying highly vulnerable structures and support investment prioritization and planning. Having a harmonized approach would be practical, given that rapid visual screening and initial assessments are a common basis for prioritization within retrofit programs. Such guidance could draw inspiration from similar efforts in the EU (for example, in Greece or Cyprus) or international examples such as the FEMA P-154 or ASCE41 Tier 1 assessments performed in the United States.

New or upgraded construction can be designed for functionality after earthquakes or other hazards, serving as a resilient hub for the larger community. For example, sports facilities, gyms, youth centers, or other facilities can be designed to become community evacuation centers in emergencies, equipped with standalone energy, communications, and first aid supplies. Not only would these facilities be useful after an earthquake, but they could also serve as extreme heat cooling centers or storm shelters.

Novel programs, incentives, and measures may be required to increase the uptake of seismic retrofits for private buildings. Such programs require considering issues such as building screening and structural assessment, retrofit implementation, and monitoring.[73] Ideally, seismic evaluation would be subsidized and the results made available and accessible in a format that nontechnical audiences can understand. To encourage implementation, governments could consider a mix of financial incentives (for example, tax reimbursements, subsidies), standardized and cost-effective retrofit procedures, clear regulatory triggers (for example, when a structural alteration is made to a building's function), and integration with other objectives (for example, energy efficiency upgrades, climate change adaptation) should all be considered. For example, Italy has introduced a building classification system that includes eight seismic risk classes ranging from A+ (highest safety) to G (lowest safety). The objective of this classification is to assess and communicate the seismic vulnerability of buildings and promote strengthening interventions through tax incentives (see Box 10). Another example of a private retrofit program in the US, Earthquake Brace and Bolt, is highlighted in Box 11.

Since older buildings tend to have inadequacies beyond their vulnerability to earthquakes, an integrated approach, such as combining seismic retrofit with improvements to energy efficiency, fire safety, accessibility, and building functionality, could yield multiple co-benefits. While 40 percent of EU buildings located within seismic-prone regions are built without modern seismic design provisions, 75 percent of EU buildings are considered energy inefficient and thus contribute significantly to CO_2 emissions.[74] This provides a significant opportunity to align seismic retrofit with energy upgrade measures. For example, an analysis of a hypothetical schools retrofit program across Austria, Bulgaria, Croatia, Cyprus, Greece, Italy, Romania, and Slovenia estimated benefit-cost ratios between 1.03 and 1.49 when considering avoided casualties, decreased damage, energy savings, and CO_2 savings.[75]

[72] World Bank 2021b.
[73] Zhang et al. 2022.
[74] Butenweg et al. 2022.
[75] World Bank 2021b.

Box 11. Example of a private retrofit program and incentive in the United States

There is evidence that private building owners will respond to incentives to seismically retrofit their buildings internationally.

In 2013, the State of California began a pilot program called the Earthquake Brace and Bolt (EBB) Program, targeting homeowners in areas designated as high risk for earthquakes that occupy cripple wall houses.[76] Cripple wall houses are wood-frame buildings typically built before 1980 that have a short wall between the foundation and a crawl space under the house, which can collapse if not properly reinforced. The EBB program offers US$3,000 to eligible homeowners to retrofit their houses. Eligible homeowners with properly retrofitted houses can then receive a premium discount of up to 25 percent on their earthquake insurance. Income-eligible homeowners may also qualify for up to US$7,000 in additional grants. After 10 years, the EBB program has assisted more than 23,000 homeowners in strengthening their homes against earthquake damage.[77]

[76] California Residential Mitigation Program. The Earthquake Brace + Bolt Retrofit. Link.

[77] Santa Barbara Independent. 2024. "Earthquake Brace + Bolt Grants Now Available to More Eligible California Homeowners." Link.

EARTHQUAKE EARLY WARNING AND PUBLIC AWARENESS

This chapter focuses on EWS, EEW, and public awareness. While long-lead time forecasting of earthquakes is not possible, short-term warnings of several seconds can be feasible, enabling protective actions that can reduce casualties or damage. Earthquake-triggered tsunamis can have longer lead times, allowing further protective action to be taken. However, timely alerts must be combined with adequate training and an educated public to successfully enhance societal resilience against earthquake risks.

Current arrangements

The EU contributes to earthquake monitoring and early situational awareness through support for rapid seismological data sharing, real-time impact mapping, and coordinated scientific observation, complementing national early warning and response efforts.

The EU has also prioritized the development of public warning capabilities that play a crucial role in ensuring timely alerts for multiple hazards, including earthquakes. Article 110 of the European Electronic Communications Code (Directive (EU) 2018/1972) requires all EU Member States to operate a public warning system that can send targeted emergency alerts to all mobile phone users in the area affected by a disaster, such as an earthquake. The deadline for transposing this requirement into national law was 2022. To further enhance public warning capabilities, the EU is developing the Galileo Emergency Warning Satellite Service (EWSS). Once operational, it will enable emergency alerts to be broadcast directly via satellites to smartphones or compatible navigation devices of people in an area affected by a disaster – even in remote locations with limited mobile coverage or when ground-based communication systems are disrupted. As public warning tools evolve, it remains essential to ensure that warning messages are clear, understandable, and accessible to all, including vulnerable groups, such as people with disabilities or those with limited digital access.

EEW systems — that allow for the detection of initial ground shaking to alert end users before imminent, stronger shaking — have been piloted or partially implemented in a few EU Member States. [78] However, their potential for widespread public alerting remains limited due to very short lead times. These are typically just a few seconds (less than one minute) between the alert issuance and the occurrence of ground shaking at target sites. Lead times vary by location and depend on several factors, including the density of seismic stations in the area, proximity to the epicenter, and the speed and accuracy of data transmission and processing. Due to these technical constraints, EEW often does not provide sufficient time for meaningful protective action in many parts of the EU—even where public warning systems are in place. Where implemented, EEW is mainly used for targeted applications. For example, Romania operates an EEW system to inform critical infrastructure (government, nuclear power plants)[79] and Italy has an EEW system triggering automatic safety measures on high-speed trains.[80] While public facing EEW applications remain rare, one example is Google's Android Earthquake Alert System, available in the EU since 2021, starting with Greece. The system shows potential of such solutions to support public warning; however, its reliability is unclear given the apparent failure in the 2023 Türkiye earthquake and its deactivation in Brazil in 2025 following false alarms.[81]

[78] Wald, D. 2020. "Practical Limitations of Earthquake Early Warning." *Earthquake Spectra* 36 (3): 1412–47. Link.

[79] Mărmureanu, A., C. Ionescu, and C. O. Cioflan. 2011. "Advanced Real-Time Acquisition of the Vrancea Earthquake Early Warning System." *Soil Dynamics and Earthquake Engineering, Prospects and Applications of Earthquake Early Warning, Real-Time Risk Management, Rapid Response and Loss Mitigation* 31 (2): 163–69. link. Italy: Link.

[80] Mărmureanu, A., C. Ionescu, and C. O. Cioflan. 2011.

[81] Clayton, J., B. Derico, and A. Foster. 2023. "Google Alert Failed to Warn People of Turkey Earthquake." *BBC*. Link. Upadhyay, Rishaj. 2025. "Google Deactivates Android's Earthquake Alerts in Brazil after False Alarm Fiasco." *Android Headlines*, February 17, 2025. Link.

Figure 6. Google's Android Earthquake Alert System

Source: Google/Alphabet.

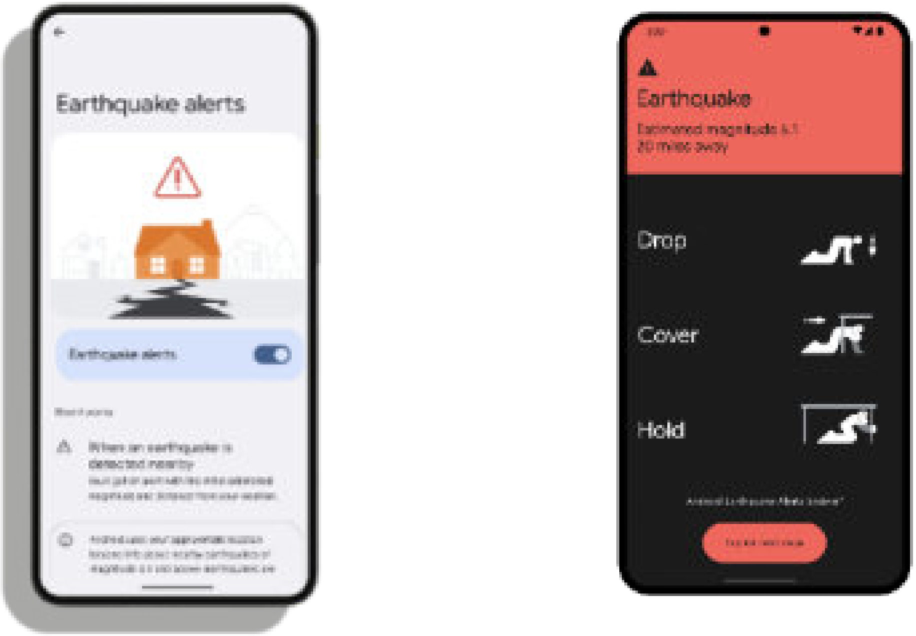

Figure 7. The global tsunami warning and mitigation system

Source: United Nations Educational, Scientific and Cultural Organization's Intergovernmental Oceanographic Commission (UNESCO IOC) 2021. Note: NEAMTWS refers to the North-Eastern Atlantic, Mediterranean, and connected seas Tsunami Warning Mitigation System.

While early warning for strong ground shaking offers only seconds of notice, aftershock forecasting provides a valuable opportunity to guide action in the hours, days, and weeks following a major earthquake. Aftershocks—smaller earthquakes that follow a mainshock—are common and can be as damaging or even more damaging (for example, the 2010–2011 Canterbury earthquake sequence in New Zealand). Unlike the mainshock, aftershocks typically follow established seismological laws, making short-term forecasts feasible. Forecasting methods were developed in Italy after the 2009 L'Aquila earthquake sequence and can estimate the likelihood of aftershock occurrence. Very few government agencies around the world have aftershock forecasting systems: the United States Geological Survey has a public-facing system, whereas the system in Italy (at INGV) is not public facing. As of 2024, ETH Zurich is developing an Operational Earthquake Forecasting service for Europe that will be made publicly available.[82]

Secondary hazards triggered by earthquakes—such as tsunamis—also require timely early warning systems. Tsunamis typically occur minutes to hours after an undersea earthquake, offering a critical window to issue alerts and coordinate evacuations before the waves reach coastal areas. The JRC develops and operates an automatic worldwide tsunami alerting system for external parties and supporting NGOs, sending messages through the Global Disaster Awareness and Coordination System (GDACS) that includes details on the estimated wave height and travel time.[83] UNESCO plays a central coordinating role through its Intergovernmental Oceanographic Commission (IOC), which oversees the Tsunami Early Warning and Mitigation System for the North-Eastern Atlantic, the Mediterranean and connected seas (NEAMTWS), designating and supporting Tsunami Service Providers across the region. Tsunami Service Providers is responsible for monitoring and issuing alerts in the North-Eastern Atlantic and Mediterranean include the CENtre d'Alerte aux Tsunamis (France), the Hellenic National Tsunami Warning Center (Greece), the Centro allerta Tsunami (Italy), the Instituto Português do Mar e da Atmosfera (Portugal), and the Regional Earthquake-Tsunami Monitoring Center (Türkiye).

Even the most advanced early warning systems depend on public understanding and appropriate response to alerts. To support this, national authorities across the EU conduct public education and awareness campaigns aimed at building earthquake resilience. These efforts include national drills, community workshops, or educational programs in schools. For example, Portugal's National Authority for Emergency and Civil Protection (ANEPC) organizes an annual campaign 'A Terra Treme' (the Earth Trembles) that educates the public on what actions to take before, during, and after an earthquake.[84] In 2024, the campaign engaged 537,826 participants in schools, 108,265 public sector staff, and 8,700 participants from the private sector. The 'A Terra Treme' website publishes materials in Portuguese, with links to information in English.

In recognition that communities are often the first responders after large earthquakes, population preparedness and self-sufficiency are essential. In March 2025, the EU Preparedness Union Strategy was launched, detailing an action plan to support EU Member States and improve the EU's capacity to prevent and respond to emerging threats, including those posed by natural hazards.[85] The strategy emphasizes a whole-of-society approach to foster a culture of preparedness and sets out to develop guidelines that enable populations to be self-sufficient in the first 72 hours after an event.

Key challenges

In the case of earthquakes, the key challenge is the short lead times that restrict protective measures. EEW provides only a few seconds of notice—enough to trigger automated systems or immediate actions like "drop, cover, and hold on," but not sufficient for mass evacuations or complex public response. In this short window, individuals must already know what to do, making personal awareness and preparedness critical.

Tsunamis triggered by earthquakes have longer lead times – but this additional time is only effective if arrangements for evacuation and response are in place. This includes evacuation plans, signage, and communities knowing where and how to evacuate. However, only a limited number of communities at risk in the EU have taken such preparedness actions. Notable examples include

[82] EFEHR. Operational Earthquake Forecasting (OEF). Link.

[83] Global Disaster Alert and Coordination System. Link.

[84] A terra A treme. 2024. Link.

[85] European Commission. 2025. "Joint Communication on Preparedness Union Strategy." Brussels. Link.

Cannes (France),[86] Samos Island (Greece)[87], Chipiona (Spain)[88], and Minturno (Italy)[89], which were all officially recognised as 'Tsunami Ready'[90] in 2024 by the UNESCO's Intergovernmental Oceanographic Commission. Being recognised as 'Tsunami Ready' requires communities to meet a set of indicators across three key areas: risk assessment, preparedness, and response. Several other coastal communities in Cyprus (Larnaca), Malta, and Spain are working towards the same recognition under the UNESCO-led CoastWAVE project, co-financed by the EU.

Despite the critical role of population readiness for seismic risks and ongoing risk communication initiatives, the level of preparedness remains low across much of the EU compared to more frequent hazards, particularly in areas that have not experienced recent seismic activity. According to the 2024 Eurobarometer survey on Disaster Risk Awareness and Preparedness of the EU Population, only 13 percent of respondents feel exposed to geological disasters such as earthquakes.[91] Even in countries like Portugal, where annual drills and week-long educational campaigns on earthquakes are conducted, civil protection stakeholders report low risk awareness among the general population.[92] Similarly, an INGV study found that only 6 out of 100 Italians living in the most seismically risky areas have an adequate perception of their earthquake risks.[93] Awareness, including the appropriate actions to take during an earthquake, is likely to be even lower in countries that do not conduct regular earthquake drills and among transient populations (for example, tourists).

Effectively communicating risk is particularly challenging for groups who are less familiar with local contexts and risks, such as refugees, immigrant communities, and tourists. These groups may not have access to the same emergency alerts or preparedness training as long-term residents, increasing their vulnerability during an earthquake or secondary hazards like tsunamis.

Trust is also essential for alerts to be effective. Even when alerts are delivered promptly, their impact depends on whether the public trusts the source and understands the message. Public trust erodes when non-critical alerts are frequent or critical events are missed. Therefore, the thresholds to trigger public alerts need to be carefully considered. The public is more receptive to information that comes through channels or sources perceived as trustworthy and is designed to consider their specific needs.[94] The challenge is that these trustworthy sources and specific needs vary widely across communities.

Key opportunities

Some countries may benefit from operationalizing EEW systems. A feasibility study of EEW in Europe indicates that Italy and Greece have higher relative feasibility than other EU Member States based on lead times, exposed population, and the average seismic intensity from large earthquakes.[95] Additionally, countries exposed to large offshore earthquakes (for example, Portugal) can have longer lead times. Some automated protective actions that could be taken during these lead times include

[86] UNESCO. 2024. Tsunami Programme. Cannes, France. Link.

[87] UNESCO. Samos Achieves UNESCO-IOC Tsunami Ready Recognition. Link.

[88] UNESCO. Chipiona Honoured as Spain's First UNESCO-IOC Tsunami Ready Recognized City. Link.

[89] UNESCO. UNESCO's Intergovernmental Oceanographic Commission (UNESCO-IOC) recognizes Minturno as Italy's first "Tsunami Ready" community. Link.

[90] UNESCO. Tsunami Ready Programme. Link.

[91] European Commission. 2024. Eurobarometer. *Disaster risk awareness and preparedness of the EU population*. Link. This percentage varies country by country. The countries with the highest perceived exposure are Greece (72 percent), Italy (56 percent), and Croatia (46 percent). Some other EU Member States with relatively high seismic risk that had lower perceived exposure include Romania (34 percent), Bulgaria (29 percent), Portugal (23 percent), and Cyprus (19 percent).

[92] Ecorys and Fraunhofer INT 2019.

[93] Instituto Nazionale Di Geofisica e Vulcanologia. The Perception of Seismic Hazard in Italy. Link.

[94] McBride, S., H. Smith, M. Morgoch, D. Sumy, M. Jenkins, L. Peek, A. Bostrom, et al. 2022. "Evidence-Based Guidelines for Protective Actions and Earthquake Early Warning Systems." *GEOPHYSICS* 87 (1): WA77–102. Link.

[95] Cremen, G., C. Galasso, and E. Zuccolo. 2022. "Investigating the Potential Effectiveness of Earthquake Early Warning across Europe." *Nature Communications* 13 (1): 639. Link.

automatically slowing down high-speed trains, stopping traffic, preventing vehicles from entering vulnerable infrastructure components (e.g., bridges), or shutting off gas pipelines. When combined with public awareness and training, individual protective actions appropriate for the local context might be taken. For example, a study investigating the implementation of a hypothetical EEW in Portugal found that average annual fatalities and injuries could be reduced by 14 percent to 24 percent, with some rupture scenarios (for example, a repeat of the 1969 M7.8 Algarve earthquake) providing a nearly 30-second lead time that cuts casualties by 50 percent.[96]

Higher density of seismic stations and seismic station networks can help advance scientific understanding and are the backbone of EWS and EEW potential. In Europe, the EMSC plays a key role in rapidly collecting and disseminating earthquake information, supported by a wide network of member seismological institutes monitoring regional seismic activity.[97] Higher coverage of seismic stations, especially near populated areas, could improve EEW potential and inform near-real-time damage predictions, which are useful in the response phase. Additional studies would be beneficial to investigate the strategic placement of seismic stations to avoid ‘blind spots’ and incorporate more detailed country-specific data in the countries where EEW seems most promising (for example, Greece, Italy, Cyprus, and southwest Portugal).

Opportunities exist to enhance earthquake awareness across the EU through dedicated earthquake awareness-raising strategies that leverage trusted information channels—such as national and local media, emergency management agencies, and social media networks. Targeted campaigns can bridge current gaps by providing clear, relatable information on seismic risks and preparedness, particularly in regions with no recent earthquake activity. These efforts should also consider various audiences, including migrants and tourists, who may lack knowledge about local seismic hazards and need accessible, multilingual resources to stay informed and safe.

A culture of preparedness can be fostered by empowering communities to be self-sufficient in the first 72 hours after a large earthquake. Risk awareness campaigns can include practical steps to increase population preparedness and self-sufficiency, such as procuring emergency supplies, creating crisis plans, or learning first aid. These actions are beneficial for earthquakes, as well as for other types of natural hazards, health emergencies, and accidents.

More EU countries can take steps to prepare for tsunamis, for example, by participating in the UNESCO’s ‘Tsunami Ready’ Program.[98] It is a voluntary, performance-based community recognition program that features 12 indicators across assessment, preparedness, and response. It supports communities in taking concrete actions such as hazard mapping, identifying people at risk, assessing community resources, evacuation mapping, installing signage, conducting outreach and education programs, conducting a biannual community tsunami exercise, planning emergency response, assessing response capacity, and disseminating alerts and warnings. Public awareness of which protective actions to take is essential, even in the absence of formal alarm systems. For example, New Zealand encourages coastal populations to immediately move to high ground or as far inland as possible in the event of strong or long ground shaking from an earthquake, and not to wait for an official tsunami warning (‘Long or Strong, Get Gone’).[99]

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[96] Silva, V., A. Taherian, and C. Oliveira. 2023. "Earthquake Early Warning for Portugal: Part 2–Where Is It Beneficial?" *Bulletin of Earthquake Engineering* 21 (9): 4091–4109.

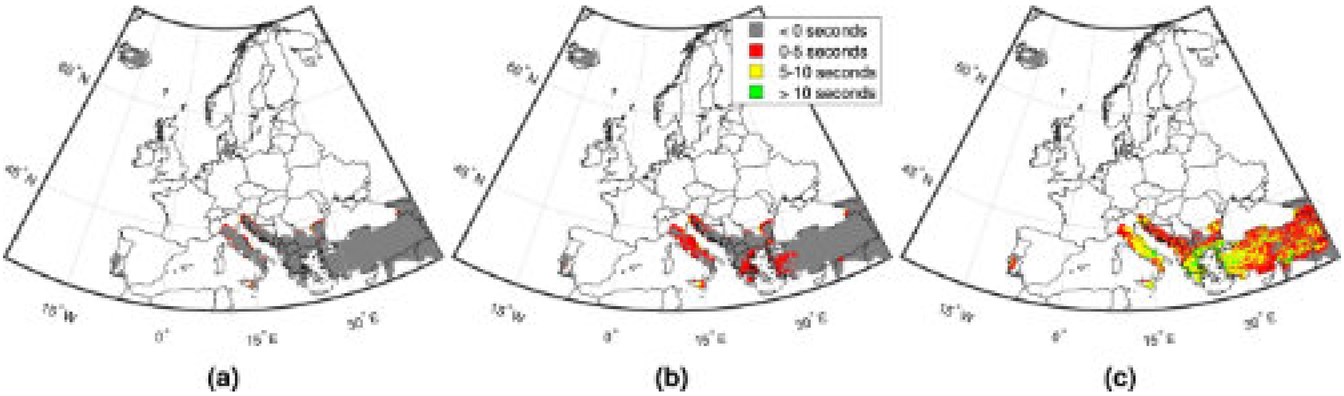
[97] CSEM-EMSC. Link. Some members include the Laboratoire de Détection et de Géophysique (LDG) in France, INGV in Italy, GeoForschungsZentrum (GFZ) in Germany, the NIEP in Romania, the U.S. Geological Survey, the European Seismological Commission (ESC) in Switzerland, and the International Seismological Centre (ISC) in the United Kingdom.

[98] UNESCO. Tsunami Ready Programme. Link.

[99] Government of New Zealand. Get Ready in and Emergency- Tsunami. Link.

Figure 8. Potential lead times from EEW according to a feasibility study across Europe

Source: Cremen, Galasso, and Zuccolo 2022. Note: These maps indicate the (1) minimum, (2) median, and (3) maximum lead times for a 0.1g EEW threshold.



EARTHQUAKE PREPAREDNESS AND EMERGENCY RESPONSE

This chapter focuses on earthquake preparedness and emergency response. Earthquake preparedness includes training and exercises as well as rescue and response capacity. Earthquake emergency response encompasses actions taken in the immediate aftermath to days or weeks after an event: search and rescue missions seek to assist trapped survivors, first aid provision, establishment of temporary shelters, restoration of basic services, mobilization of community volunteers, and building safety inspections.

Current arrangements

Earthquake-affected countries, both within and outside the EU, can request assistance from the UCPM through the ERCC, which coordinates the deployment of response teams and the delivery of aid.[100] Between 2007 and early 2025, the UCPM provided emergency assistance for 32 earthquake-related disasters, including 5 within the EU (Greece, Italy, Croatia). This assistance ranged from search and rescue teams, emergency medical teams, and field hospitals to medical items, temporary shelters, and other relief items. UCPM assistance comes from two key sources: the European Civil Protection Pool (ECPP) and rescEU. The ECPP consists of voluntarily pre-committed response capacities from EU Member States and UCPM participating states, ready for rapid deployment when requested. RescEU is a strategic reserve of European capacities fully funded and owned by the EU, designed to step in when national resources and the ECPP are overwhelmed or unavailable.

Post-earthquake urban search and rescue (USAR) operations play a crucial role in saving lives, as teams locate, extract, and provide medical aid to survivors. Speed is critical, as people rarely survive within rubble for longer than a few days. USAR requires highly specialized training and equipment, underscoring the importance of training programs and resource pooling. The International Search and Rescue Advisory Group is a global network under the United Nations umbrella of over 90 Member States and organizations, establishing minimum international standards for teams and a methodology for international coordination in earthquake response. The UCPM and International Search and Rescue Advisory Group have a long-standing partnership of cooperation, working together to align European USAR teams with internationally recognized standards, strengthening coordination in earthquake response efforts worldwide.

The EU also supports rescue and recovery operations with near-real-time data, risk information, and situational awareness. The EU's Copernicus Emergency Management Service offers a range of mapping products for immediate damage assessment and long-term planning, along with satellite-based geospatial data to enhance situational awareness and decision-making for emergency responders.[101] Beyond alerting about the occurrence of hazards, the GDACS issues fully automated, real-time impact estimations for earthquakes and tsunamis within 20–25 minutes of their occurrence.[102] The ERCC cooperates with scientists to assess the impact of earthquakes and tsunamis on populations and critical infrastructure.

Post-earthquake building inspection and tagging inform emergency response and increase public safety, but approaches vary by country. After an earthquake, buildings need engineering inspections to ensure they are safe to occupy. Typically, a building is tagged afterward to inform the public whether the building is usable, restricted, or inaccessible. After recent earthquakes in the EU, different countries have taken different approaches to building inspection and tagging. For example, Italy uses an AeDES survey form that distinguishes between six usability categories.[103] In Greece, three levels are assessed: 'green' for safe for use, 'yellow' for temporarily unsafe for use, and 'red' for dangerous for use. After the 2020 Samos earthquake, the Technical

[100] European Commission. Emergency Response Coordination Center. Link.

[101] Copernicus EMS. Link.

[102] GDACS - Global Disaster Alert and Coordination System. Link.

[103] Di Ludovico, M., G. De Martino, A. Prota, G. Manfredi, and M. Dolce. 2021. "Damage Assessment in Italy, and Experiences after Recent Earthquakes on Reparability and Repair Costs." In *Advances in Assessment and Modeling of Earthquake Loss*, 65–84. Springer International Publishing Cham.

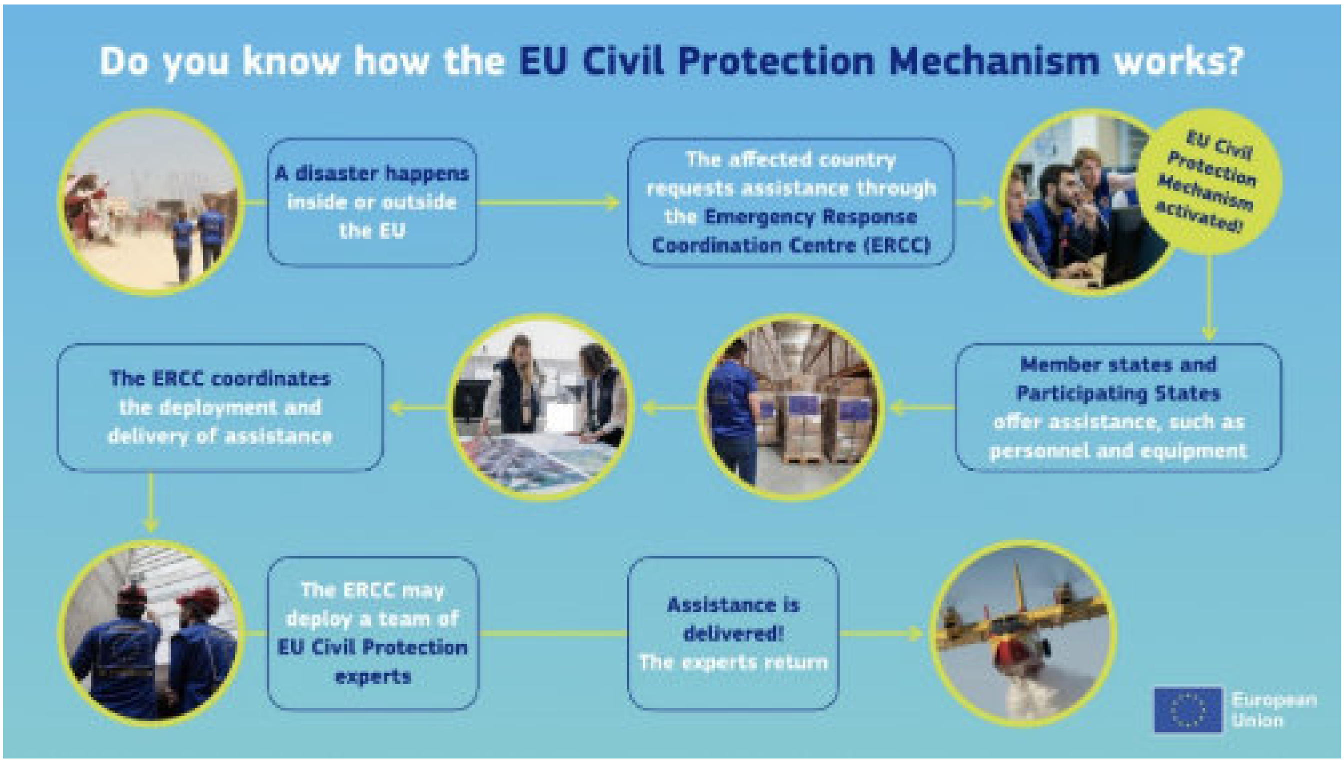
Chamber of Greece created a Registry of Engineers for Response and Action during emergencies, which would facilitate deployment in future earthquakes. However, countries that have not experienced damaging earthquakes in recent years are less likely to have procedures in place.

Exercises can help strengthen preparedness for response across multiple stakeholders and improve host nation support services. The UCPM actively supports this through its exercise programme. For example, in 2024, two UCPM-funded projects were launched, involving full-scale earthquake response exercises. Exercise MAGNITUDE took place in the border region of Baden-Württemberg, bringing together over 950 participants from Germany, Austria, Greece, France, and Switzerland. It tested procedures for requesting international assistance and coordination of response units.[104] Another earthquake exercise, DEMONAX, will take place in Cyprus and will provide an opportunity to address challenges unique to an earthquake-prone island. The exercise will test national emergency plans, cooperation with the UCPM, search and rescue operations, and coordination under scenarios involving widespread damage to critical infrastructure and cultural heritage sites.[105]

[104] European Union. 2024. *Magnitude: Germany Hosts Major EU Civil Protection Exercise*. Link.
[105] European Commission. 2024. *EU Funding & Tenders Portal*. Link.

Figure 9. The UCPM in the emergency response phase of disasters

Source: European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations. Link.



Key challenges

Emergency response facilities and other critical entities (e.g., hospitals, distributed infrastructure systems) are crucial for disaster response activities but can be at risk of damage and disruption in an earthquake. An exposure analysis shows that over 25 percent of fire stations in Bulgaria, Croatia, Cyprus, Greece, Italy, Portugal, Romania, and Slovenia are exposed to high seismic hazards.[106] Ensuring that these facilities are resilient and can remain operational in an earthquake is a priority for strengthening overall disaster response. Disruptions to these facilities or other essential infrastructure can also cause cascading impacts (e.g., lost communications or roads blocked by debris or landslides delay the arrival of emergency care) However, limited data exist on the vulnerability of these entities that could help prioritize strengthening.

Large earthquakes often cause extensive damage that can exceed an individual country's capacity, but inconsistencies in building inspection procedures and the lack of a unified certification across EU Member States limit opportunities for mutual aid. This can prevent timely building inspections and damage assessment, increasing risks to life from aftershocks and stalling recovery. For instance, although the Azores region in Portugal has specific guidelines for the rapid post-earthquake assessment of buildings, the number of engineers or architects available to perform such assessments would likely be insufficient for a large earthquake.[107] The need to strengthen post-earthquake assessment capacity was also highlighted in Bulgaria's Disaster Risk Management Plan from 2022, which identified the development of a methodology for rapid assessment of buildings and establishing an organization of trained engineering volunteers as two of the highest priorities.

Key opportunities

While existing tools providing near-real-time risk information and situational awareness are valuable, there is room for additional support and further enhancement. Continuous investment is required to improve data reliability, dynamic integration, and the ability to account for real-world complexities in earthquakes, such as secondary perils (for example, liquefaction, landslides) and aftershocks. Expanding seismic station networks near urban centers would improve tracking of ground shaking, while installing sensors on critical buildings could enable the rapid diagnosis of their structural integrity and susceptibility to damage. One example where the latter technology has been implemented is Catania, Italy.[108] Furthermore, existing or newly developed earthquake loss models can be employed and tested to provide rapid forecasts of likely impacts.[109]

There is an opportunity to unify post-earthquake inspection and tagging approaches across the EU and establish corresponding training and certification programs. This would facilitate the rapid international deployment of qualified engineers when needed. Existing national frameworks (for example, those in Greece, Italy, and Croatia) could serve as valuable starting points. An EU-level guide could be developed for inspectors in the field, similar to the ATC-20[110] used in the United States, but adapted to the European building stock[111] and translated into national languages.

Targeted retrofit of emergency response facilities in moderate to high seismic hazard areas of Europe can reduce potential disruptions in response. Such programs could mitigate the damage and impacts observed in recent earthquakes. For example, 20 civil protection buildings were damaged in the 2020 Petrinja earthquake in Croatia, five so heavily that they were deemed unusable.[112] Targeted retrofit of such facilities has proven to be cost-effective, with benefit-cost ratios ranging from 1.59 to 3.29 in Italy, considering avoided direct damage, casualties, and disruptions in future earthquakes.[113]

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106 World Bank and European Commission 2024.

107 Ecorys and Fraunhofer INT 2019.

108 Observatorio Sismico Urbano. The OSU Project (Urban Seismic Observatory - City of Catania). Link.

109 See for example, the ARISTOTLE-ENHSP Project in Europe (link) or the SIRED-RD loss assessment tool in the Dominican Republic (link).

110 Applied Technology Council. ATC-20 Building Safety Evaluation Forms and Placards. Link.

111 Anagnostopoulos, S., M. Moretti, M. Panoutsopoulou, D. Panagiotopoulou, and T. Thoma. 2014. "Post Earthquake Damage and Usability Assessment of Buildings: Further Development and Applications." *Final Report*. Link.

112 Government of Croatia 2021.

113 World Bank 2021b.

EARTHQUAKE RECOVERY, RECONSTRUCTION, AND POST-DISASTER FINANCING

This chapter covers earthquake recovery, reconstruction, and post-disaster financing. This refers to actions taken after the response phase when priorities shift toward restoring affected areas, rebuilding buildings and infrastructure, and helping communities return to normal.

Current arrangements

Recovery and reconstruction after earthquakes is a long-term process, often taking many years or even decades. Some examples of recovery activities in recent EU earthquakes are described in Box 12. It also presents a dual challenge: the urgency to restore essential services and infrastructure quickly while also ensuring reconstruction efforts enhance long-term resilience. Balancing speed with deliberation is critical, as rushed repairs may lead to future vulnerabilities, whereas well-planned rebuilding can reduce risks and improve safety for generations.[114]

Earthquake recovery in the EU is mainly financed by national and EU budgetary instruments (e.g., reserve funds, contingent lines of credit, grants), with few countries relying more prominently on insurance. At EU level, support is available through the EUSF and cohesion policy funds, which can assist Member States in post-earthquake recovery and reconstruction. Within the EUSF's framework, earthquakes have been the second most costly hazard after floods, receiving €3.4 billion in EUSF payouts since 2002 for disasters in Croatia, Greece, Italy, and Spain. The earthquake-related interventions supported by the EUSF since 2002 are presented in Table 1. National financing instruments within EU Member States vary but generally include a mix of reserve and contingency funds, budget reallocation, contingent lines of credit, tax increases, post-disaster funds, and sovereign insurance products. A study on the Economic Analysis of Prevention and Preparedness in the EU showed that the sum of the EUSF, reserve funds, and contingency funds available to Member States covers on average less than 4 percent of total government liabilities each year when analyzed from an EU perspective considering earthquakes and floods.[115] It is expected that the remaining liabilities are funded through ad hoc risk financing instruments, such as borrowing, budget reallocation, donor aid, or increased taxation.

Key challenges

Most countries do not have an overarching national or local recovery framework to guide earthquake recovery. This gap often contributes to challenges in the aftermath of earthquakes, hindering timely and effective rebuilding. Following the 2020 Croatia earthquakes, several obstacles emerged, including slow administrative processes that delayed reconstruction approvals and restricted property owners from starting repairs independently.[116] Limited co-financing measures, covering only a portion of structural renovations, discouraged investments, while unresolved ownership disputes, particularly in rural areas, further stalled progress. Rising construction costs, exacerbated by increased demand and the COVID-19 pandemic, strained resources and diminished owners' capacity to contribute. Additionally, the high proportion of culturally significant buildings required specialized restoration efforts, complicating and slowing the process. These challenges highlighted the need for adaptive frameworks to address barriers in disaster recovery. Post-disaster recovery frameworks help governments and relevant stakeholders plan for a large-scale recovery effort and guide prioritization in a more transparent and informed manner. Yet, limited examples of such approaches exist in the EU, with the General Directorate of Natural Disasters Recovery in Greece being one of them (see Box 13).

[114] Johnson, Laurie A., and Robert B. Olshansky. 2017. *After Great Disasters: An In-Depth Analysis of How Six Countries Managed Community Recovery*. Cambridge: Lincoln Institute of Land Policy. Link.

[115] World Bank 2021a.

[116] Sigmund, Radujković, and Atalić 2022.

Box 12. Examples of recovery activities after recent EU earthquakes

Recent approaches to recovery after damaging earthquakes have often prioritized critical infrastructure and public assets, residential buildings, and cultural heritage.

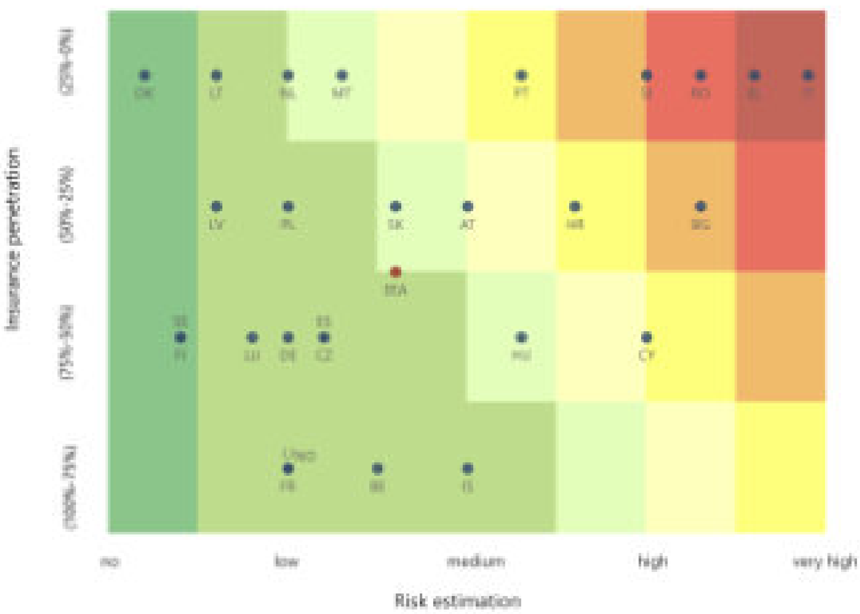
Following the 2020 Croatia earthquakes, recovery efforts included establishing a reconstruction fund, streamlining administrative processes for recovery, providing financial support for structural repairs, demolition, and reconstruction of private housing, and addressing the specific needs of cultural heritage buildings that were affected by the earthquakes.[117] After the 2016–2017 earthquakes in Central Italy, notable recovery activities included providing assistance to displaced households, restoring schools and education services, assessing the conditions of artistic and cultural heritage assets, disposing of waste from damaged buildings and areas hosting displaced populations, and supporting the livestock sector.[118]

[117] Sigmund, Z., M. Radujković, and J. Atalić. 2022. "The Role of Disaster Risk Governance for Effective Post-Disaster Risk Management—Case of Croatia." *Buildings* 12 (4): 420. Link.

[118] IFRC. 2022. *Disaster Recovery and Reconstruction in Italy: A Legal and Policy Survey*. Geneva, Switzerland: IFRC. Link.

Figure 10. Earthquake insurance penetration and risk estimation in European Economic Area (EEA) countries in 2024

Source: European Insurance and Occupational Pensions Authority (EIOPA) Dashboard on insurance protection gap for earthquakes, last updated on November 26, 2024. Link.



Box 13. Example of a disaster recovery framework in Greece

Some EU Member States, such as Greece, have established disaster recovery frameworks that guide earthquake recovery actions, facilitating coordination and timeliness.

Originally established in 2017, the General Secretariat for Natural Disasters Recovery and State Support is a specialized body under the Ministry for Climate Crisis and Civil Protection. It is responsible for managing state support mechanisms and coordinating recovery efforts following disasters caused by natural hazards such as earthquakes, floods, and wildfires. Its mandate includes mobilizing engineering teams, approving state aid and interest-free loans, and managing temporary and permanent housing programmes.

The Secretariat's role is illustrated by the recovery efforts following the 2020 Samos Island earthquake.[119] The Secretariat deployed 90 engineers to assess the safety of buildings and determine housing needs. Through a phased process, buildings were classified based on usability, guiding decisions on demolition, repairs, and emergency shelter provision. This structured response facilitated targeted assistance, enabled

[119] Cetin, Kemal, George Mylonakis, Anastasios Sextos, Jonathan Stewart, Burak Akbaş, Mustafa Akgün, Sinan Akkar, et al. 2020. "Seismological and Engineering Effects of the M 7.0 Samos Island (Aegean Sea) Earthquake." 10.18118/G6H088.

the prioritization of reconstruction actions, and informed broader policy decisions.

The majority of earthquake damage and losses are borne by the housing sector, often displacing residents in both the short and long term. After earthquakes, residents may evacuate due to aftershocks and concerns about additional hazards in heavily affected areas. A subset of these households may be unable to return after the emergency phase, particularly if their housing has become uninhabitable because of the earthquake.[120] This creates demands not just for emergency shelter and temporary accommodation but also for permanent housing. For example, the 2009 L'Aquila earthquake in Italy left over 67,000 people homeless: immediately post-event, nearly 36,000 were accommodated in camps with tents and nearly 32,000 accommodated in hotels and private homes.[121] Seven years after the earthquake, roughly 20 percent of the displaced population had not returned. These experiences underscore the need for housing recovery strategies that go beyond temporary shelter and integrate long-term reconstruction planning and social support.

An EU-wide analysis for earthquakes and floods highlighted sizable macro-fiscal impacts with limited DRF arrangements, leaving 96 percent of liabilities to be covered through ad hoc financing.[122] Insurance penetration rates for public and residential assets are low across the EU, especially in countries with higher seismic hazard (see Figure 10). For example, roughly 80% of economic losses were insured after the 2010-2011 Canterbury earthquake sequence in New Zealand, but only 14% of economic losses were insured after the 2009 L'Aquila earthquake in Italy.[123] Moreover, reserve funds only exist in a few countries, the EUSF contributes only a small percentage of total damage (5 percent on average), and no sovereign insurance or capital market instruments have been identified. For the 100-year return period earthquake, fiscal impacts could exceed 7–17 percent of the gross domestic product (GDP), depending on the level of government liability. Furthermore, these financing measures take time to establish and disburse. For example, typical timing for EUSF includes 8–10 weeks for applications and an average of 56 weeks for disbursement (with some possibility for advances).[124]

The EUSF has limitations in the scale of financial assistance available, the scope of eligible interventions, and the time frame for implementation. The fund primarily functions as a solidarity mechanism to assist recovery, as its resources are limited and allocated based on predefined thresholds, covering only a small portion of total reconstruction costs. The EUSF only covers public expenditure and must be used within 18 months, whereas recovery after large earthquakes typically extends over several years. Furthermore, the EUSF funding is restricted to restoring 'to the working order' or pre-disaster condition, preventing its use for BBB approaches that could reduce risks from future disasters or improve energy efficiency.[125] Building back better is particularly relevant in areas where the damaged infrastructure is already outdated and physically vulnerable.

Key opportunities

Strengthening national disaster recovery frameworks offers an opportunity to improve the speed, coordination, and effectiveness of post-earthquake recovery. Such frameworks help governments define key principles, roles, and preliminary recovery programs before a disaster occurs. They might, for example, set key planning and policy considerations, develop effective institutional structures, and create dedicated reconstruction funds to finance post-disaster rebuilding. They can also introduce legislative frameworks to streamline reconstruction processes, implement zoning strategies to manage land use changes, allocate financial support for rebuilding, enforce building safety regulations, and promote community engagement.[126] These frameworks may also provide guidance for monitoring progress in recovery, including data collection. Although it is impossible to anticipate all recovery needs or challenges for a specific disaster event in advance,

[120] Paul, Nicole, Carmine Galasso, and Jack Baker. 2024. "Household Displacement and Return in Disasters: A Review." *Natural Hazards Review* 25 (1). Link.

[121] Di Ludovico et al. 2021.

[122] World Bank 2021a; World Bank. 2024a.

[123] King, Andrew, David Middleton, Charlotte Brown, David Johnston, and Sarb Johal. 2014. "Insurance: Its Role in Recovery from the 2010–2011 Canterbury Earthquake Sequence." *Earthquake Spectra* 30 (1): 475–91. Link.

[124] World Bank 2024a.

[125] Regulation (EU) No. 661/2014 of the European Parliament and of the Council of 15 May 2014 Amending Council Regulation (EC) No. 2012/2002 Establishing the European Union Solidarity Fund. 2014. OJ L. Vol. 189. Link.

[126] GFDRR. 2020. *Disaster Recovery Framework Guide*. Revised version. World Bank Group. Link.

frameworks can include room for flexibility to adapt to practical challenges.

Integrating DRF into recovery planning is a way to ensure that financial resources are available when they are most needed after an earthquake.[127] Establishing coherent communication on available post-disaster funding, promoting best practices for national disaster risk financing, and encouraging risk-layering approaches could help Member States strengthen post-disaster financing and close funding gaps. In line with Directive (EU) 2024/1265 on national budgetary frameworks, Member States are required to integrate disaster and climate risks into fiscal planning, reinforcing the need for structured DRF strategies that anticipate and manage the financial impacts of future disasters.

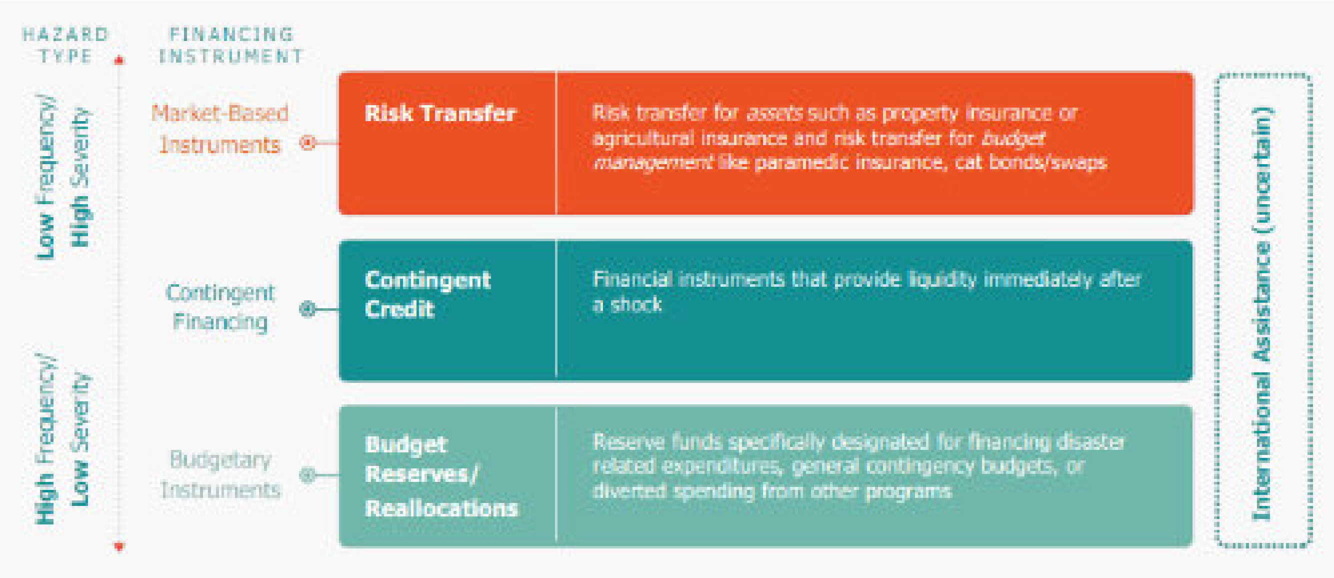
EU Member States have substantial room to develop more comprehensive DRF strategies based on a risk-layering approach. Current national and EU-wide post-disaster funding mechanisms remain insufficient, especially for large-scale events such as earthquakes, and earthquake insurance penetration remains low. [128] A risk-layered DRF strategy combines a variety of financial tools—such as emergency funds, insurance, and international assistance—so that each type of disaster risk (from frequent small events to rare major catastrophes) is managed with the most appropriate funding source (Figure 11). Budgetary instruments are typically more suitable for high-frequency, low-severity events, while market-based risk transfer instruments are more effective for high-risk events that occur less frequently, such as earthquakes. An example of a risk-layering approach to address insurance protection gaps at the EU level is presented in Box 14, which is relevant for all natural hazards, including earthquakes.

Incentivizing household or public insurance uptake could significantly reduce government liabilities for future earthquakes or other hazard events. [129]This could also be accomplished through new EU-wide regulations and policies establishing minimum coverage requirements. However, regulatory aspects required to support such a large uptake in insurance would require investigation. National governments could consider options for increasing household catastrophe insurance. These could include public-private partnerships (PPPs) (for example, Consorcio de Compensación de Seguros in Spain, Caisse Centrale de Réassurance in France) or private schemes (for example, PAID in Romania).[130]

[127] World Bank 2024a.
[128] Ibid.
[129] World Bank 2021a.
[130] EIOPA (European Insurance and Occupational Pensions Authority) and ECB (European Central Bank). 2024. *Towards a European System for Natural Catastrophe Risk Management*. Link.

Figure 11. Disaster risk-layering approach — no single instrument can address all risks

Source: World Bank.



Box 14. Example proposed solution to address the catastrophe insurance protection gap in the EU

The European Central Bank (ECB) and the European Insurance and Occupational Pensions Authority (EIOPA) propose a two-pillar solution to address the growing insurance protection gap at the EU level, anchoring it in a risk-layering approach and building upon existing EU-level and national structures.

In their joint paper published in 2024, the ECB and the EIOPA recommend:[131]

- An EU-level public-private reinsurance scheme: Intended to increase insurance coverage where current coverage levels are low, this scheme would pool private risks across the EU and across different perils, acting as a stabilizing mechanism over time. The scheme could be funded by risk-based premiums from (re)insurers or national schemes. Access to this scheme would be voluntary. It is intended to complement—not replace—national schemes and private market initiatives.

- An EU fund for public disaster financing: Intended to improve public disaster risk management among EU Member States, payouts from this fund would support reconstruction after high-loss disasters, conditional on the implementation of risk mitigation policies. The scheme would be funded by EU Member State contributions, which would be adjusted to reflect their respective risk profiles. Membership in this scheme would be mandatory.

[131] Ibid.

CROSS-CUTTING TOPIC: SOCIAL RESILIENCE AND INCLUSION

This chapter covers social resilience and inclusion in the context of earthquakes. Beyond physical damage, earthquakes induce multidimensional impacts on people that affect their livelihoods and personal well-being and can have ripple effects on the economy. The degree of impact on a given household depends on both physical and socioeconomic characteristics. For example, a wealthier household may be able to access financial savings and housing insurance to afford repairs to its dwelling, while a less wealthy household may not have access to resources and face obstacles in accessing financing in a timely manner, hindering recovery.

Current arrangements

Earthquakes and other disasters disproportionately affect socially vulnerable households and increase existing poverty levels, creating a poverty trap. For example, an exploratory analysis of survivors in three recent Italian earthquakes found that older individuals with lower education were more likely to be displaced and have increased difficulty exiting the displaced condition.[132] The 2019 earthquake in Albania pushed an additional 26,000 people into poverty (2.3 percent increase) within affected districts.[133] While strong earthquakes are rare, they tend to cause much more extensive damage to Europe's residential buildings than more frequent hazard events (for example, floods, storms). This poses a large-scale recovery challenge, affecting populations that depend on damaged buildings and infrastructure (for example, residents, employees, employers). Poor and marginalized groups have the lowest capacity to cope with these disruptions, with challenges likely exacerbated during the protracted recovery process.

There are notable correlations between the vulnerability of the housing stock and socioeconomic vulnerability, which exacerbate disparities in damage and recovery. Poor housing conditions amplify the effects of disasters, as they are more likely to experience significant damage or collapse. Socially vulnerable groups (e.g., low-income households, elderly) are also more likely to occupy poor housing conditions, making them more likely to experience disproportionate damage in an earthquake.[134] When combined with a more limited coping capacity, these groups are more likely to face significant recovery challenges and hardships.

Examples of efforts for social inclusion in disaster risk management and earthquake preparedness in the EU exist. This includes Romania's modernization of preparedness tools through the National Disaster Risk Reduction Strategy (NDRRS) 2024–2035 and the Strategy for Strengthening the Role of the Department for Emergency Situations within the National Emergency Management System (2024–2030).[135] These reforms aim to enhance multi-hazard emergency preparedness for vulnerable groups by improving accessibility of the website Fii Pregatit ('Be Prepared'), promoting preparedness for disaster and climate risks, including hazard-specific preparedness plans for individuals, and integrating information specific to people with disabilities and those at risk of gender-based violence. Additionally, Romania is strengthening first responders' capacities through dedicated training on identifying and addressing gender-based violence cases in emergencies, ensuring survivors are linked to essential services. The reform efforts also emphasize collaboration with civil society organizations and the National Authority for the Rights of People with Disabilities, aligning with broader EU and national strategies on climate adaptation, social inclusion, and gender equality.

Social protection programs play an important role in social inclusion and have been used as a channel for post-disaster support, which has become known as adaptative social protection (ASP). ASP is an approach that integrates social protection, disaster risk reduction, and

[132] Savadori, L., D. Di Bucci, M. Dolce, A. Galvagni, A. Patacca, E. Pezzi, G. Scurci, and F. Del Missier. 2024. "Quality of Life in Displaced Earthquake Survivors." *Progress in Disaster Science* 24: 100371. Link.

[133] Government of Albania, World Bank, United Nations Development Programme, and European Commission. 2020. *Albania: Post-Disaster Needs Assessment. Volume A Report*.

[134] World Bank. 2021c. *Overlooked: Examining the Impact of Disasters and Climate Shocks on Poverty in the Europe and Central Asia Region*. Washington, DC, US: World Bank. Link.

[135] World Bank. 2024b. *Romania: Second DRM Development Policy Loan with a Cat DDO*. World Bank Group. Link.

climate change adaptation to help vulnerable populations anticipate, absorb, and recover from shocks, such as natural disasters or economic crises. Examples of types of ASP tools relevant to earthquakes include post-event cash transfers or vouchers, subsidized or mandatory earthquake insurance, temporary housing or rental assistance, employment or income support programs, targeted social protection for vulnerable groups, reconstruction grants for safe housing, educational continuity support, and relocation assistance for those in high-risk areas. ASP systems can allow the parameters of benefits (for example, level, frequency, duration) to vary in the case of emergencies and crises. An example implementation and recommendations for ASP in the EU are described in Box 15.

Key challenges

Despite growing recognition of the social impacts of disasters, significant knowledge and data gaps remain in understanding who is most affected and how to target support effectively. Most existing damage and loss data are at the aggregate level, providing limited insight into disparities across population subgroups and who has the greatest recovery needs. At the same time, guidance on which socioeconomic characteristics are important to disaggregate across (for example, income level, age) are not well established. Moreover, the mechanisms that contribute to social vulnerability are often context-specific: for example, gender may be more critical to consider in a society that is more gender imbalanced, while income levels may be more critical to consider in a society with a more limited safety net.

Traditional risk assessments have focused on property damage and economic loss, which highlights the wealthiest groups as the most at risk simply because they have the most economic value to lose.[136] However, decades of evidence after past disaster events show that poor and marginalized groups are hardest hit in disasters. Disaster risk models can estimate the consequences after events such as earthquakes and prioritize risk reduction strategies, but prioritizing strategies based solely on property and economic loss may inadvertently deepen existing social inequalities. Similarly, prioritizing post-disaster aid based on property damage and economic loss rather than need can further exacerbate inequality. For example, quantitative longitudinal evidence in the United States has proven how post-disaster aid can exacerbate wealth gaps.[137]

[136] Hallegatte et al. 2020.
[137] Howell, J., and J. Elliott. 2019. "Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States." *Social Problems* 66 (3): 448–467. Link.

Box 15. Examples of ASP in the EU

Social protection in the EU can be made adaptive to emergencies and crises, including earthquakes.

In Bulgaria, in response to COVID-19, the government expanded social assistance for low-income families, increased heating allowances, and introduced top-up payments for pensioners. Unemployment benefits were extended, and grants were provided to low-income self-employed individuals. Wage subsidies of 40–60 percent were offered to affected businesses, and over 550,000 households received food packages.

A study investigating the potential for ASP in Romania, considering disasters such as floods and earthquakes, recommended guaranteed minimum income and family support allowance, heating assistance, emergency aid, child social services, child state allowance, unemployment benefit, and mobility premia programs.[138]

[138] World Bank. 2023b. *Towards Adaptive Social Protection in Romania*. World Bank Group. Link.

There have been several efforts to understand social vulnerability across the EU, but the mechanisms through which earthquakes exacerbate vulnerability across different communities and the measures needed to mitigate post-disaster vulnerability remain poorly understood. This challenge is further compounded by unclear institutional responsibilities, leaving it ambiguous who is accountable for reducing vulnerability and managing its consequences, where communities are often left relying on volunteer efforts or peer support.[139] It should be noted that definitions and understandings of vulnerability vary significantly across European countries and even within institutions in the same country, where some countries focus on predefined 'vulnerable groups', while others adopt more situational or dynamic perspectives.

Social protection systems are not yet adaptive to shocks such as earthquakes and other disasters. Traditionally, responses to shocks and disasters have mainly been through emergency assistance. Ministries responsible for social policy are often not involved directly in disaster recovery, and thus, the extension of social protection measures in emergencies is usually ad hoc.

Key opportunities

Improved data collection could facilitate understanding who is disproportionately affected by earthquakes. There are several opportunities to improve data collection: disaggregating damage and impact metrics by socioeconomic characteristics, reporting impacts over time to understand recovery needs (for example, shelter counts over time, returned population over time), and considering alternative risk metrics to damage and economic loss.

Earthquake risk assessments could similarly explore human-centered risk metrics and disaggregated losses. Human-centered risk metrics might include, for example, well-being losses or household displacement. Disaggregated risk estimates can also provide a view of which population subgroups carry disproportionate risk and recovery needs. For example, an analysis conducted by the World Bank for Greece reveals that higher-income groups experience greater total losses from earthquakes and floods in absolute terms, but lower-income groups face disproportionate impacts relative to their income and consumption.[140] It also shows that well-being losses exceed direct asset losses, especially for poorer groups.

Policy actions should reflect community recovery needs and their ability to recover (or not) from earthquakes and other disasters, not just absolute economic loss amounts.[141] For example, a study evaluating a hypothetical policy to reduce the asset vulnerability of the poor by 30 percent (for example, through structural retrofit) estimated a 45 percent increase in overall socioeconomic resilience[142] in Romania considering future earthquakes and floods.[143] Such a policy was also found to avoid roughly US$160 million losses annually due to future earthquakes and floods in both Bulgaria and Romania, as well as approximately US$140 million in Greece. These findings highlight the value of targeted policy measures informed by indicators of social vulnerability, such as socioeconomic status, age, and health conditions (factors included in tools like the EU Atlas of Demography).[144]

Effective ASP systems can be built by integrating disaster risk management with social protection frameworks to enhance resilience and responsiveness to shocks. This requires comprehensive data on household-level disaster risk, improved interoperability of social protection and disaster risk data systems, and legal frameworks that enable automatic and scalable ASP interventions. Governments can benefit from prioritizing pre-agreed financial mechanisms for disaster response, ensuring timely assistance to vulnerable populations. Additionally, fostering institutional coordination and capacity building among social protection and DRM agencies can strengthen preparedness and ensure adaptive responses to future crises.

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139 Orru, Kati, et al. 2022. "Approaches to 'Vulnerability' in Eight European Disaster Management Systems." *Disasters* 46 (3): 742–67.

140 World Bank 2021c.

141 Lallemant, D., S. Loos, J. McCaughey, N. Budhathoki, and F. Khan. 2020. *Informatics for Equitable Recovery: Supporting Equitable Disaster Recovery through Mapping and Integration of Social Vulnerability into Post-disaster Impact Assessments*. Link.

142 Socioeconomic resilience refers to the economy's ability to absorb the impact of consumption changes due to well-being losses due to asset losses or the ability of an affected population to cope with and recover from disaster losses, which plays a key role in explaining why the poor are disproportionately affected by disasters.

143 World Bank 2021c.

144 European Commission, Knowledge Centre on Migration and Demography (KCMD) Data Portal. Atlas of Demography. Link.

CROSS-CUTTING TOPIC: PRIVATE SECTOR

This chapter covers private sector involvement in earthquake risk management. Relevant stakeholders might include building owners and property managers, insurance companies, business owners, utility providers, construction and engineering firms, nongovernmental organizations, and nonprofits.

Current arrangements

The private sector and businesses have several critical roles in earthquake risk management. They are key actors in preparedness, response, and recovery; facilitate scaling up of risk reduction activities; act as knowledge creators and technology innovators; and provide risk transfer mechanisms through insurance and insurance-linked products.

Businesses are part of the affected community after earthquakes and play a role in recovery by identifying and deploying resources, providing expertise and equipment, and offering goods and services. For example, after the 2023 earthquake in Türkiye, local businesses immediately began sending in-kind donations, including trucks, blankets, generators, portable toilets and bathrooms, heaters, and more.[145] Similarly, after the 2020 Croatian earthquakes, engineers from private firms contributed to writing the post-earthquake damage inspection manuals used for damage inspection and contributing to reconstruction efforts.

The private sector can also support innovation and technology for earthquake risk management. This could range from investment in research and development programs, development of innovative seismic-resistant design techniques and materials, advanced data analytics, deployment of EWSs, or creation of innovative risk transfer products. For example, the EU-funded HYCAD project involved eight academic and private partners in the development of innovative seismic-resistant construction solutions that could be easily repaired after an earthquake.[146] A notable example of PPP is the GEM Foundation based in Italy, which provides scientific data and resources to aid understanding of earthquake hazards and risks. Public partners include the Department of Civil Protection in Italy, while private partners include a multitude of insurers and reinsurers (for example, Allianz, Aon, Munich Re, Partner Re). Through this arrangement, several specific projects have informed understanding of earthquake hazards and risks in the EU and globally.

Beyond operational and technological contributions, the private sector also central plays a role in risk financing, particularly through the development and deployment of insurance and capital market instruments that help transfer earthquake risk. Different market-based instruments may make sense depending on the frequency and the severity of the event. Some market instruments include insurance pools, reinsurance, and reinsurance pools. These instruments can reduce financial risks by diversifying portfolios, increasing stability, and transferring excess risks. Additionally, alternative risk transfer instruments exist, such as catastrophe (CAT) bonds. CAT bonds allow the issuer to raise funds for disaster response through a high-yield debt, which pays out only if a predefined event, such as an earthquake, occurs. Unlike traditional insurance, which requires time-consuming assessments of actual losses after an event, these products are triggered by pre-agreed, measurable parameters – such as ground shaking intensity – and can deliver funds much faster than claims-based insurance. One example is Swiss Re's parametric insurance product QUAKE, which provides a pre-agreed loss amount when

145 CBi (UN Connecting Business initiative). 2023. "In Türkiye, Local Businesses on the Front Line of the Earthquake Response and Recovery Effort." Link.

146 EU-RFCS Project. 2019. HYCAD. Link.

ground shaking at the insured location(s) exceeds a defined threshold.[147]

Key challenges

As part of the affected community, businesses face damage and disruption after earthquakes, but these risks are poorly understood. While some larger enterprises have the capacity to assess and enhance business continuity in disasters, small and medium enterprises often lack risk information, assessments, and tools for mitigation. Access to business continuity guidance, financial strategies, and incentives remains limited.

Although some promising examples exist, partnerships with the private sector in earthquake risk reduction and planning remain limited. Existing PPPs are mainly concentrated in the (re)insurance sector, engineering consultancies, and construction firms. A promising example of wider private sector involvement in disaster risk management can be found in Cyprus, as described in Box 16.

Key opportunities

There is an opportunity to use earthquake scenarios more effectively for engaging businesses, establishing cross-sectoral connections, improving understanding of earthquake risks, and increasing preparedness. Such scenarios are often developed as part of NRAs and academic research to assess potential impacts based on hypothetical or historical earthquake events. They can also be a useful tool for communicating future risks to a wide range of stakeholders. Additional efforts could be made to engage the private sector in earthquake scenario exercises. An international example of this can be found in Box 17.

Governments could incentivize businesses to reduce potential disruption after an earthquake by implementing and regularly discussing business continuity plans. These plans might include pre-identifying engineers to inspect facilities post-earthquake, establishing alternative working arrangements (for example, remote working) for staff in the case of building disruption, deciding what communications need to be sent to employees during recovery, and setting priorities for actions needed during recovery. Business emergency and continuity plans need to be regularly discussed, updated, and actionable to be successful. An international example of how governments can encourage business continuity planning for earthquakes is FEMA's QuakeSmart program, which navigates organization leaders through a three-step process to identify risks, develop and execute an action plan, and become recognized to encourage others.[148]

PPPs could also help in a range of ways, such as incentivizing the uptake of private retrofits, overcoming challenges in large infrastructure recovery projects, and more. Through PPPs, disaster risk reduction actions could be linked to additional benefits. For example, the California Earthquake Authority in the United States developed a Brace + Bolt program, where homeowners are provided up to US$3,000 to strengthen the foundation of their older homes to reduce earthquake damage, after which they may qualify for a 25 percent discount on their earthquake insurance premium (see Box 11).[149] In some cases, PPPs can also help overcome challenges related to large infrastructure recovery projects by leveraging private funds, management skills, and expertise. For example, four years into the recovery effort after the 2011 Great East Japan Earthquake and tsunami, a private consortium signed a 30-year concession to operate the Sendai Airport, making it the first state-owned airport operated by the private sector.[150] The Miyagi Prefecture expected privatizing airport operations would help revitalize the local economy more quickly.[151]

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147 SwissRe. QUAKE: Parametric insurance to close the earthquake protection gap. Link.
148 FEMA. QuakeSmart. Link.
149 California Earthquake Authority. About CEA Brace + Bolt. Link.
150 Sasamori, S., and N. S. Naho. 2018. "Learning from Japan: PPPs for Infrastructure Resilience." *World Bank Blogs*. Link.
151 World Bank. 2017. *Resilient Infrastructure Public-Private Partnerships (PPPs): Contracts and Procurement*. Link.

Box 16. Example of private sector engagement in disaster risk management

The Cyprus example shows how private sector can be meaningfully engaged in disaster risk management through networks and corporate social responsibility strategies.

The SupportCY network of the Bank of Cyprus is a network of over 180 private companies and organizations that cooperate with the bank to assist the State during national or international crises and disasters, including earthquakes. The network aims to meet the various needs of the Cypriot society within the broader Corporate Social Responsibility (CSR) Strategy of the Bank.[152] The SupportCY network has also become a central point of response, as it created the SupportCY Volunteers Corps, a group of 116 volunteers, including 40 trained individuals ready to act immediately and support frontline professionals in emergency situations, including earthquakes. Additionally, the SupportCY network conducts preparedness activities that include a large storage of emergency equipment and humanitarian aid, as well as awareness campaigns, including some on earthquakes.[153] It also has initiatives for disaster risk awareness in vulnerable populations (for example, children, elderly people).

Box 17. International example of private sector engagement in earthquake scenarios

The private sector can be effectively engaged through earthquake scenario exercises, helping stakeholders understand and prepare for potential risks.

The United States Geological Survey led an earthquake scenario project called the 'HayWired Scenario', which aimed to quantify realistic impacts of a potential magnitude 7.0 earthquake on the Hayward Fault in California's San Francisco Bay Area.[154] As part of this project, the United States Geological Survey collaborated with a wide range of local stakeholders, including fire department chiefs, emergency managers, utility providers (for example, water, gas, electric), transportation agencies, and the information technology industry. These partnerships involved over 50 agencies and businesses, formalized as the 'HayWired Coalition'. Engagement spanned workshops, meetings, trainings, and exercises held over the course of a year. These engagements provided opportunities to examine regional lifeline and infrastructure dependencies across different providers, encourage businesses to develop and share earthquake recovery plans, discuss the cost and performance trade-offs of more stringent building codes, and more. Although the project has since been completed, the HayWired[155] remains available, offering information and topic-based discussion questions, allowing ongoing engagement.

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152 Bank of Cyprus. SupportCY. Link.

153 Bank of Cyprus. SupportCY - Actions. Link.

154 Hudnut, K.W., A.M. Wein, D.A. Cox, K.A. Porter, L.A. Johnson, S.C. Perry, J.L. Bruce, and D. LaPointe. 2018. "The HayWired Earthquake Scenario—We Can Outsmart Disaster." *U.S. Geological Survey Fact Sheet 2018–3016*, 6 p., Link.

155 Earthquake Country Alliance. HayWired Scenario Exercise Toolkit. Link.

INVESTMENT NEEDS AND RECOMMENDATIONS

This chapter proposes key priorities for reforms and investment areas, which may be considered as part of technical assistance, policies, or instruments. It is informed by desk research and consultations.

1. As EU Member States continue confronting significant seismic vulnerabilities, targeted investments across all dimensions of disaster risk management are vital to bolster earthquake risk management and resilience throughout the EU. Earthquake risk reduction requires a strategic, inclusive, and sustained approach. Investment decisions should be guided by a clear understanding of seismic risk, prioritization based on exposure and vulnerability, strong governance, and the alignment of short-term actions with long-term resilience goals. Investment must address not only physical infrastructure but also institutional capacity, scientific knowledge, public engagement, and financial preparedness. The EU and national efforts should aim to align earthquake risk reduction with climate adaptation, energy efficiency, and social equity objectives—leveraging synergies and avoiding fragmented approaches. Recommended areas of institutional reforms and investment are summarized below.

2. EU Member States are encouraged to proactively develop strategic frameworks for earthquake risk reduction and recovery. These frameworks should define priorities, clarify institutional responsibilities, strengthen cross-sectoral coordination, and integrate seismic risk into broader disaster and climate agendas. A major gap remains in planning for the post-disaster recovery phase, which should outline how recovery will be organized, led, prioritized, and financed—so that reconstruction can begin swiftly and with a focus on long-term resilience. Taken together, these efforts support more strategic and effective risk reduction in advance of disasters and enable faster and more resilient recovery when earthquakes occur.

3. Strengthening institutional and technical capacity, particularly at the subnational level, is essential for the effective design, implementation, and monitoring of earthquake risk reduction measures. This includes training of engineers, emergency planners, building inspectors, and municipal officials; development of guidance and standards; and knowledge exchange mechanisms. Support and capacity building are particularly important to help smaller municipalities translate national frameworks into local action.

4. To meaningfully address the primary driver of earthquake risk in the EU—a vulnerable and aging building stock—seismic retrofit programs must be scaled up and guided by clear prioritization frameworks, integrated approaches, and strengthened safety standards. With the majority of buildings in the EU constructed before the implementation of modern seismic-resistant design practices, a large number of buildings remain at risk of damage and collapse in a future earthquake. As retrofit needs are vast, it is important to establish prioritization frameworks that help target resources where they are most needed. A key priority within this effort is the retrofitting of critical infrastructure essential for saving lives and maintaining continuity of services during and after an earthquake. Tiered approaches to screen and assess the seismic vulnerability of buildings have already been developed and tested in some EU Member States and internationally, offering a basis for developing more unified guidance applicable across the EU. Seismic vulnerability considerations should also be systematically integrated into existing initiatives—such as energy efficiency upgrades and the resilience of critical entities—to maximize co-benefits and implementation efficiency. The forthcoming update of Eurocode 8 offers a key opportunity to strengthen seismic safety standards across the EU. Its full potential can be realized through active implementation and enforcement by Member States, supported by capacity building and technical guidance where needed.

5. **Encouraging greater private initiative by addressing financial and behavioral barriers to retrofitting can accelerate uptake, particularly in the housing sector.** Targeted incentives and programs, such as co-financing schemes, tax credits, or insurance-linked incentives, can motivate homeowners and property managers to take action. These efforts should be complemented by risk awareness campaigns, targeted outreach, and user-friendly guidance to make retrofitting more accessible and actionable for individuals.

6. **Increased effort is needed to strengthen public risk awareness and community-level preparedness for earthquakes and tsunamis, which remain low across much of the EU.** Investments should support targeted awareness campaigns, local preparedness drills, accessible information tools, and partnerships with schools, civil society, and media. Efforts must be inclusive, ensuring that messaging and preparedness resources are accessible to all population groups, including more vulnerable communities.

7. **Investments are needed to strengthen EWS, including EEW, where feasible.** This involves expanding and modernizing seismic monitoring infrastructure, reducing detection-to-alert time, improving alert dissemination channels, and promoting interoperability across borders. Public education, system testing, and integration with emergency response protocols are essential to ensure warning systems are trusted and actionable.

8. **Advancing earthquake risk understanding for informed decision-making requires continued investment in scientific research, data collection, and assessment tools.** Expanding seismic station coverage, conducting microzonation studies, and developing detailed building inventories would strengthen earthquake risk assessments. Development of EU-level tools like the DRMKC Risk Data Hub should be complemented by investments in higher-quality national data. Efforts should address gaps in disaggregated and human-centered impact metrics to better understand which population groups face disproportionate risk and to guide more equitable risk reduction and recovery. Further research is also needed on aftershocks and secondary hazards such as liquefaction and tsunamis to build a more holistic risk picture.

9. **Building long-term financial resilience is as important as physical risk reduction.** This requires integrating disaster (and climate) risk into fiscal planning, in line with Directive (EU) 2024/1265, and applying risk-layered approaches to disaster risk financing. Public-private partnerships and risk transfer instruments (such as catastrophe bonds or insurance pools) can help diversify funding sources and reduce pressure on public budgets.

A detailed list of recommendations is provided in Table 4.

Table 4. Key investment recommendations for the EU in earthquake risk management

Risk governance	• Develop earthquake-specific national risk reduction strategies, plans, and investment. programs to ensure efficient risk prevention and reduction. • Create road maps and action plans for prevention and reduction activities at local levels. • Implement integrated programs for seismic retrofit and energy efficiency. • Integrate earthquake risk reduction into existing EU energy efficiency investments.
Understand-ing risk	• Use risk information at local levels, including seismic microzonation and land use planning. • Create building inventories and gather data that inform needs for both seismic retrofit and energy upgrades. • Systematic and accessible data collection on loss and damage. • Support research to improve understanding of secondary perils triggered by earthquakes, such as tsunamis, landslides, liquefaction, and fire following. • Data collection and systemic risk assessment for critical entities.
Risk preven-tion, reduction, and mitigation	• Accelerate seismic retrofit programs, especially for critical entities and infrastructure. • Offer EU-level guidance on a tiered approach to screening, assessing, and prioritizing existing buildings for retrofit and reconstruction. • Design new or upgrade existing construction considering functionality after earthquakes. • Develop novel retrofit programs for private buildings. • Integrate seismic retrofit with energy efficiency, fire safety, accessibility, and functionality improvements.
Early warning and public awareness	• Consider the feasibility of EEW systems in addition to general EWSs. • Increase the density of seismic stations. • Enhance public awareness of earthquake risks through trusted information channels. • Foster a culture of preparedness and self-sufficiency in the first 72 hours. • Take steps to prepare for tsunamis in coastal communities.
Preparedness and emer-gency response	• Continually test and develop methods to forecast earthquake impacts to provide situational awareness and inform rescue and response missions on the ground. • Standardize inspection and tagging processes, such as through training and certification programs that enable rapid, cross-country deployment and mutual aid. • Undertake targeted retrofit of emergency response facilities to reduce potential disruptions in earthquake response.
Recovery, reconstruc-tion, and post-disaster financing	• Proactively prepare for earthquake recovery through disaster recovery legislation and frameworks while allowing flexibility to adapt to practical challenges. • Integrate DRF strategies within the recovery framework. • Adopt a risk-layering approach in DRF strategies. • Incentivize insurance uptake to reduce government liabilities.
Social resilience and inclusion	• Improve data collection after events, expanding coverage of human-centered metrics and socioeconomic or demographic information to understand disparities in impact and recovery. • Consider human-centered risk metrics and disaggregated losses in earthquake risk assessments. • Consider community recovery needs and the community's ability to recover rather than just absolute economic loss amounts. • Make existing or planned social protection systems adaptive to shocks such as earthquakes.
Private sector	• Leverage earthquake scenarios as a tool to engage businesses and establish cross-sectoral connections. • Encourage private sector engagement and business continuity planning. • Consider the potential of PPPs across the earthquake risk management cycle.

ANNEX 1: REFERENCES

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