ESPREssO Vision Paper
on future research strategies following the Sendai Framework for DRR 2015-2030

(October 2018)

ESPREssO
Enhancing Synergies for disaster PRevention in the EurOpean Union

Vision Paper

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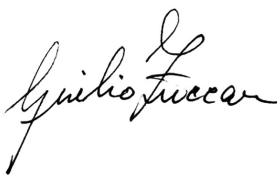

Preface

Economic losses from natural hazards have increased almost ten-fold over the past 40 years *, with yearly losses of around ten billion euros within the European Union (EU) alone. In addition, there is an increasing awareness that the objectives of the Sustainable Development Goals (SDGs), the 2015 Paris Agreement and the Sendai Framework for Disaster Risk Reduction cannot be achieved without a comprehensive approach that is able to promote the effective implementation of science and evidence-based Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) policies and measures. This international landscape of agreements provides, for the first time, a more comprehensive agenda to achieve key resilience objectives, with approaches consistent with the complexity of the challenge, overcoming the limits of traditional siloed approaches. The expected increase and worsening consequences of disasters induced by natural events in Europe entail the need for coordinated action among the Member States to strengthen the resilience of their physical assets and communities, as well as their capacity to respond to multiple types of hazards.

The ESPREssO Vision Paper aims to support the preparation of the Horizon Europe Framework Programme by identifying future research challenges in the field of natural hazards and risk management, in relation to the priorities defined by the Sendai Framework for Disaster Risk Reduction[1] and the related EU Action Plan 2015-2030[2] aimed at mainstreaming DRR into all EU policies, by supporting the pathways to implementation within the Horizon Europe Framework Programme 2021-2027, in continuity with the key outcomes and actions identified by the UNISDR Science and Technology Roadmap[3].

The ESPREssO project[4] "Enhancing Synergies for Disaster Prevention in the European Union" is a Coordination and Support Action funded by the EU's Horizon 2020 Research and Innovation programme under grant agreement No. 700342.

In its implementation, ESPREssO has been committed to identifying the existing gaps and needs in the research, policy and legislation domains of natural hazards and risk assessment, preparedness, mitigation and response. ESPREssO considered the many ongoing initiatives at European and Global levels on these issues, with the aim of providing a harmonised framework that is able to capture the complexity of this field in terms of research and innovation and deliver a synthesized view of the emerging priorities.

The present document is the result of intense networking activities that have been carried out over the last two and a half years through the ESPREssO Stakeholder Forums and Think Tanks, which have focused on the key challenges identified, and through the participation of project partners at external events promoted by relevant EU and global institutions.

The paper has taken advantage of an extensive review process which has involved, in addition to the consortium partners and Advisory Board, a large network of experts in the field of DRR, CCA and DRM, representatives from the ESPREssO Stakeholders' group, from the FP7/H2020 research community, and from key EU and global institutions, such as the European Environment Agency (EEA), the Covenant of Mayors for Climate and Energy, the Community of Users on Secure, Safe and Resilient Societies (CoU), the JRC Disaster Risk Management Knowledge Centre (DRMKC) and the UNISDR Science and Technology Platform.

* http://www.swissre.com/library/2015_financial_report.html, http://reports.weforum.org/global-risks-2018/
1 https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf
2 http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf
3 https://www.preventionweb.net/files/45270_unisdrscienceandtechnologyroadmap.pdf
4 www.espressoproject.eu

Executive summary

EU policies and strategies in the field of DRR are progressively shifting from a mere "safety" issue to broader approaches affecting multiple scientific, governance, policy and social areas, emphasizing the strict interconnection between risk reduction and sustainable development at global level. Moreover, the significant shift from managing 'disasters' to managing 'risk', as highlighted in the Sendai Framework for Disaster Risk Reduction, suggests to set the basis and foster opportunities for increased coherence and mutual reinforcement across the post-2015 agendas and for this to be reflected in policies, institutions, goals, indicators and measurement systems for implementation.

This report represents the contribution of ESPREssO project "Enhancing Synergies for Disaster Prevention in the European Union" towards a new strategic vision on Disaster Risk Reduction and Climate Change Adaptation in Europe and to promote new ideas for the future roadmap and agenda of natural hazard research and policymaking over the next ten years.

The project identified three key challenges, **1) Integrating DRR and CCA to foster resilience, 2) Integrating Science and legal/policy issues in DRR and CCA and 3) Improving national regulations to prepare for transboundary crises,** which have constituted the main framework around which ESPREssO has built a strong network with relevant stakeholders and institutions across the EU over three years. The findings from ESPREssO Stakeholder Forum held in Bonn (May 2017), and the three Think Tanks held in Berlin (October 2017), Zurich (January 2018) and Napoli (April 2018) have been confronted with the four priorities of the Sendai Framework for Disaster Risk Reduction 2015-2030, with the aim of identifying, in a structured way, the **emerging issues and key cross-cutting topics** for the future EU Research and Innovation agenda.

In relation to the **Understanding Disaster Risk** priority, there is the need for **advanced simulations and assessments**; the implementation of **interdisciplinary research** with a systemic perspective; improved **data management and information updates; harmonised data, protocols and procedures** that take advantage of technological innovation; **co-creation of knowledge** among all involved actors and communities and efficient **communication and dissemination platforms.**

Strengthening risk governance to manage disaster risk will require procedures and tools to improve **knowledge-based decision-making**; the effective implementation of **whole community governance models**; enhancing the exploitation of existing **synergies between policies (DRR, CCA and Sustainable Development Goals)**; the strengthening of **transboundary cooperation** along the entire Disaster Risk Management cycle and **improved legal frameworks** to support informed decision-making and continuous consultation with involved communities. Effectively **investing in DRR for resilience** will require funding **knowledge** to anticipate and prepare for emerging risk conditions; **implementation** to disseminate the best practices experimented in various sectors across EU; **multi-risk resilience** to increase cost-effectiveness of investments; **country-specific** and **international priorities** in a balanced way and **resilience awareness** to take benefit of community action in DRR and CCA.

Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction will require a **widespread application of Build Back Better principles** as a way of optimizing the available resources; the **evolution of early warning systems** both in technological and organizational terms; an evolution of **transboundary coordination and cooperation** mechanisms taking into account emerging hazards induced by climate change; and **improved communication to the general public** focused on the protection of vulnerable communities and the transparency of decision making.

Along with such cross-cutting issues, **relevant research gaps and needs exist in relation to hazard-specific topics. Extreme weather, forest fires, earthquakes, volcanic eruptions, tsunami, na-tech and hydrogeological hazards** are mapped according to their relevance across EU countries (including EU Civil Protection Mechanism Member States, i.e. EU28 plus Iceland, Montenegro, Norway, Serbia, Former Yugoslav Republic of Macedonia and Turkey), highlighting relevant research projects funded by the European Commission in the last decade, and the main **priorities identified by the scientific community.**

In relation to the **Research and Innovation topics in the field of natural hazards that should be reflected in the next Horizon Europe Framework Programme**, the ESPREssO vision presents the identified gaps and needs and addresses them in the form of five broad "missions" (terminology introduced in the Horizon Europe Framework) which outline the scope and expected impact of the proposed actions. The five missions are as follows:

New frontiers in the field of probabilistic simulation models, vulnerability and risk assessment are to be explored, including theoretical advancements to align modelling frameworks in different EU Member States and to embed cascading effects, early warning and real-time simulations into reliable decision-support tools.

Increased quality, reliability and availability of data for performing quantitative assessments is needed, in support of the improvement of DRR and CCA policies and measures along the entire cycle of emergency. It should take advantage of technological innovation in the field of earth observation, big data acquisition and management, IT infrastructure and cloud computing.

Improved risk governance approaches should be explored, and should aim to strengthen horizontal coordination, overcome existing silos in governmental institutions devoted to DRR and CCA and clarify roles and liability among involved actors at all levels. This should also include streamlining "top down" and "bottom up" policies, moving towards participatory models that go beyond mere risk awareness and communication issues, and instead focus on community engagement mechanisms able to operationalize knowledge-sharing across relevant sectors (e.g. in the field of social science, ecology, security, environment, etc.) and provide an added value in terms of risk prevention and management.

Overcoming the "implementation gap" requires the promotion of innovative approaches to exploit the results of research advancements into resilience-driven investments to mitigate risks and adapt to changing social and environmental conditions, identifying cost-effective DRR and CCA paths based on key emerging concepts, such as "all-hazards", "adaptive mitigation" and "build back better" approaches.

An effective integration of social and behavioural sciences in DRR, CCA and DRM domains is recommended, both in terms of advanced modelling and assessment methods, towards enhancing community building and awareness as a driver to reduce the socio-economic impact of natural hazards and improve emergency management procedures.

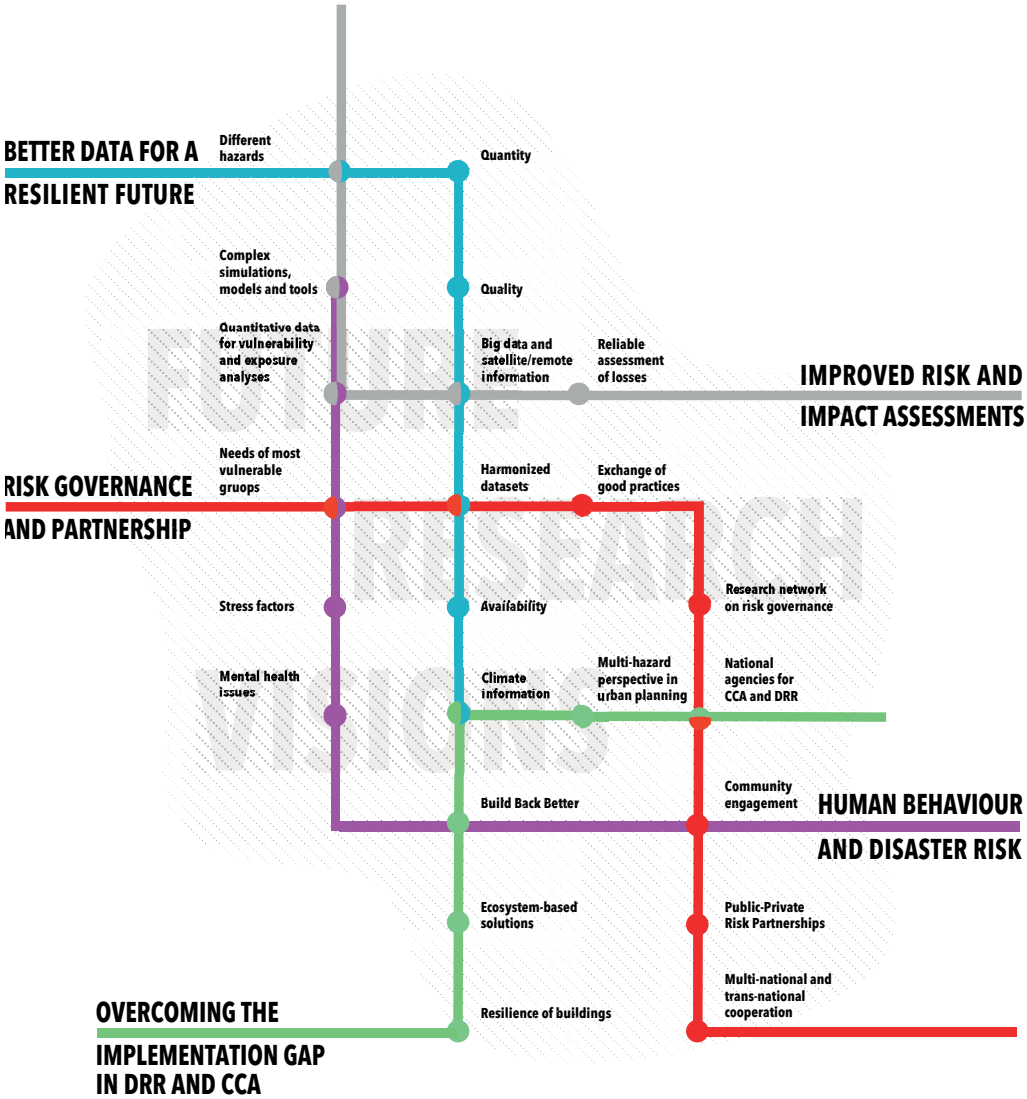

Figure 1: *The five research missions of the ESPREssO Vision Paper and their interconnections*

1 Introduction

1.1 Overall context

Past and recent catastrophic events with severe impacts have demonstrated how human society has become more exposed and vulnerable to risk associated with extreme natural hazard events, and how existing global inequalities often exacerbate both the exposure and vulnerability of communities, infrastructures and economies. The evolution of key concepts such as vulnerability, resilience and sustainability is acting to shape a more holistic framework, which includes issues ranging from the quantification of expected impacts of multiple hazards on the built environment and society as a whole, to the organizational aspects and governance strategies in the different phases of the emergency management cycle (prevention, preparedness, response, recovery).

EU policies and strategies in the field of DRR are progressively shifting from a mere "safety" issue to broader approaches affecting multiple scientific, governance, policy and social areas, emphasizing the strict interconnection between risk reduction and sustainable development at global level. Moreover, the significant shift from managing "disasters" to managing "risk", as highlighted in the Sendai Framework for Disaster Risk Reduction, implies to set a basis and foster opportunities for increased coherence and mutual reinforcement across the post-2015 agendas, to be reflected in policies, institutions, goals, indicators and measurement systems for implementation.

Understanding and exploiting the existing linkages and synergies between The Paris Agreement on climate change, the Sendai Framework and the Sustainable Development Goals (SDGs), represents, in this sense, a global priority for future research and innovation actions in the field of natural hazards. Common resilience pathways emerging from different scientific and operational domains still need to be explored in terms of their implementation potential. It also requires the strengthening of opportunities for transdisciplinary and transboundary joint efforts in order to organize and structure, with all the relevant actors, a new strategy for the Horizon Europe Framework. The Sendai Framework, in particular, aims at a significant paradigm shift from managing "disasters" to managing "risk", identifying basis and opportunities for increased coherence and mutual reinforcement across the post-2015 agendas reflected in policies, institutions, goals, indicators and measurement systems for implementation. The different backgrounds of DRR and CCA domains – the first emerging from the field of risk sciences, emergency management and humanitarian aid, the latter from the environmental sciences and increasingly recognized as a global challenge affecting society as a whole – have so far limited the establishment of an integrated methodological and operational approach to DRR and CCA in a multi-risk modelling and design-oriented perspective. Europe, through its regulatory and funding initiatives, as well as being a committed partner within the relevant UN governance and policy actions, is providing a significant effort in bridging the two perspectives, despite these perspectives still suffering from an "implementation gap". This gap results from the observed disparity between a sufficient knowledge base and an insufficient up-take by authorities. In some cases, this has been linked to uncertainties in climate change scenarios and a lack of coordination between different governance levels and funding sources at national and international levels. Nonetheless, synergies between DRR and CCA are emphasized in all the main strategies and agreements at the EU level (e.g. EU Adaptation Strategy for Climate Change (EUAS); Cohesion policy; Macro-regional strategies). One such synergy is that they reflect a common goal: to reduce the impacts of extreme weather and increase resilience to disasters, particularly among vulnerable populations. The clear benefits of linking and integrating the knowledge base, as well as policies and practices, emerge when considering DRR and CCA from this perspective.

DRR and CCA are considered to be cross-cutting fields across EU governance structures devoted to Cooperation and Development (DG-DEVCO)[5], Climate Action (DG-CLIMA)[6], Environment (DG-ENV)[7], Civil Protection and Humanitarian Aid (DG-ECHO)[8]. This implies the need to identify synergies and integration opportunities in relation to land use, urban development, social issues, environmental protection, emergency planning and response. At the same time, the link with global processes and their implementation is at the heart of European policies, and this implies the need to build coherence around risk-informed approaches developed through international cooperation (Sendai Framework for DRR; Paris Agreement on Climate; 2030 Agenda for Sustainable Development; New Urban Agenda).

5 https://ec.europa.eu/europeaid/general_en
6 https://ec.europa.eu/clima/
7 http://ec.europa.eu/dgs/environment/index_en.htm
8 https://ec.europa.eu/echo/

Many of the recent geophysical and climate-related events, such as the Ejafjallajökull eruption in 2010, the Nepal earthquake in 2015, the Elbe and Danube floods in 2013, the increasingly hot temperatures, dry seasons and resulting forest fires, have highlighted how disasters caused by natural events have no respect for jurisdictional borders. This leads to the need for transboundary cooperation with regards to adaptation, mitigation and long-term preparedness efforts, as well as for emergency management and response coordination. In this sense, the outcomes of 2017 European Forum for DRR promoted by UNISDR reflect the alignment between EU and UN positions towards the objective of strengthening DRR and CCA integration within a transboundary perspective.

Despite its fragmented socio-political identity, but (at the same time) thanks to the community status and the solidarity principles linking the 28 countries of the Union, Europe represents one of the most compelling areas worldwide for experimenting and testing evolutionary approaches to national regulations based on transboundary priorities and implementation opportunities arising from the collaboration of many diverse individual countries in view of defined common objectives.

Some large ongoing EU initiatives that are developing shared tools/services among Member States can strengthen the required data/knowledge sharing and the coordination capability processes. To name a few: Copernicus through its Emergency Management[9] & Climate Change Service[10], is enabling a pan-European access to advanced and high resolution satellite data; The Disaster Risk Management Knowledge Centre (DRMKC), which aims at enhancing the EU and Member States resilience to disasters and their capacity to prevent, prepare and respond to emergencies through a strengthened interface between science and policy, the ambitious Aristotle (All Risk Integrated System Towards Transboundary holistic Early-warning)[11] project aimed at providing a nearly real time simulation system and rapid impact assessment to be used within the context of emergency management; GR2ASP (Geospatial Risk and Resilience Assessment Platform)[12] project focused on critical infrastructures' vulnerability, resilience and impact assessment, while also taking into account network interdependencies and potential cascading effects, and many other EU funded projects (e.g. The H2020 DRS cluster projects EU-CIRCLE, ANYWHERE, BRIGAID, RESIN, STORM, etc.). The effective implementation of such tools/services will allow the Member States to have access to a wealth of background knowledge and decision-support tools, useful to streamline the national policies towards DRR and CCA objectives, improving the standardization of approaches and procedures, and thus simplifying also the procedures at EU level with regards to financing transboundary adaptation and mitigation measures through the existing collaborative programmes (e.g. H2020; Life+), and development and cohesion funds (e.g. ESF; ERDF).

From an emergency management perspective, another significant achievement in Europe is the 2013 EU Civil Protection Mechanism, currently in the process of being updated to better answer to a number of challenges related to humanitarian aid. Significant issues are explicitly tackled, such as: National Civil Protections coordination around the EU Civil Protection Mechanism (EUCPM)[13] humanitarian aid and NGOs cooperation; coordination of large investments programmes for resilience and adaptation in neighbouring countries; improvement of international (extra-EU) cooperation to tackle the aggravating impact factors of disasters caused by natural events due to specific context conditions (e.g. because of migrations, wars, pandemics, social inequities and injustice).

The position of the UNISDR EU Platform, expressed at the European Forum on Disaster Risk Reduction 2017 in Istanbul, reflects the consolidated and emerging challenges related to DRR and CCA, which connect the European science and policy innovation within a shared international perspective.

1.2 ESPREssO project background

The ESPREssO project "Enhancing synergies for disaster prevention in the European Union", funded within the European Programme Horizon 2020 aims to contribute to a new strategic vision on DRR and CCA in Europe and to promote new ideas on what should be a future roadmap and agenda for natural hazard research and policymaking over the next ten years.

The project has identified three key challenges which represent emerging priorities for research, policy and practices in the field of DRR and CCA:

- Challenge 1: Integrating DRR and CCA, to propose ways to create more coherent national and European approaches and resilience strengthening;

9 http://emergency.copernicus.eu/
10 https://climate.copernicus.eu/
11 http://aristotle.ingv.it/
12 https://ec.europa.eu/jrc/en/grrasp
13 http://ec.europa.eu/echo/what/civil-protection/mechanism_en

- Challenge 2: Integrating science and legal/policy issues in DRR and CCA, to enhance risk management capabilities by bridging the gap within these domains at local and national levels;

- Challenge 3: Improving national regulations to prepare for transboundary crises, to address the issue of efficient management of disasters induced by natural hazards (including cascading effects and NaTech) requiring a coordinated effort from two or more countries in the EU, and/or the support of the EU Civil Protection Mechanism.

The three challenges have constituted a framework around which ESPREssO has built its activities, ranging from an extensive literature review, to networking actions at the EU and global levels, to dedicated events organized by the ESPREssO partners involving a wide range of external stakeholders, including some national platforms. In addition, an Action DataBase[14] (ADB) has been developed and filled with a hundred entries. The ESPREssO-ADB provides an opportunity to formalise discussions and to store content in a synthetic format. It relies on a short questionnaire enabling stakeholders to describe any project, programme or initiative dealing with the topics of ESPREssO. The criteria described in the questionnaire are used to characterize the efficiency of an action in several fields and allow quick searching and altering. Once this information is classified, the ESPREssO-ADB proposes a compilation of good ideas and effective practices, which can be transposed to other scales, or background, in order to help scientists and decision-makers develop efficient strategies.

All these activities have allowed the ESPREssO consortium to identify significant gaps and needs in terms of the required actions and activities that are advised to be implemented, derived from the analysis of scientific literature and of the existing policies and legislation at global/EU/national levels, reflected and complemented by the vision of global/EU core groups dealing with DRR and CCA (such as the UNISDR, Community of Users on Safe, Secure and Resilient Societies (CoU); Joint Research Centre (JRC), the Disaster Risk Management Knowledge Centre (DRMKC); European Environment Agency (EEA); FP7 and Horizon 2020 projects and by the ESPREssO stakeholders community, involved in the stakeholders forum and think tanks).

Accordingly, this ESPREssO Vision Paper is the result of an intense collaborative effort, reflecting the feedback from a large community of stakeholders, going beyond the specific expertise of consortium members and the specific key challenges identified.

Five priority areas (or 'mission') have been identified as a result of a critical analysis of possible research challenges in the framework of the upcoming Horizon Europe Framework programme:

1. New frontiers in the field of probabilistic simulation models, vulnerability and risk assessment, including theoretical advancements to align modelling frameworks in different EU Member States and to embed cascading effects, early warning and real-time simulations into reliable decision-support tools (see Section 4.3);

2. Increased quality, reliability and availability of data needed to perform quantitative assessments, in support of the improvement of DRR and CCA policies and measures improvement along the entire cycle of emergency, taking advantage of technological innovation in the field of earth observation, big data acquisition and management, IT infrastructure and cloud computing (see Section 4.4);

3. Improved risk governance approaches, aimed at strengthening horizontal coordination and overcoming existing silos in governmental institutions devoted to DRR and CCA, clarifying roles and liability among involved actors at any level, as well as streamlining "top down" and "bottom up" policies towards participatory models that go beyond mere risk awareness and communication issues, to be focused on community engagement mechanisms able to operationalize knowledge-sharing across relevant sectors (e.g., in the field of social science, ecology, security, environment, etc.) and provide an added value in terms of risk prevention and management (see Section 4.5);

4. Promotion of innovative approaches to exploit the results of research advancements into resilience-driven investments to mitigate the risks and adapt to changing social and environmental conditions, identifying cost-effective DRR and CCA paths based on key emerging concepts, such as "all-hazards", "adaptive mitigation" and Build Back Better approaches (see Section 4.6);

14 http://adb-espresso.brgm.fr

5. Effective integration of social and behavioural sciences in DRR, CCA and DRM domains, both in terms of advanced modelling and assessment methods, towards enhancing community building and awareness as a driver to reduce the socio-economic impact of natural hazards and improve emergency management procedures (see Section 4.7).

The insight and feedback collected throughout the project during the Think Tanks (TTs) and the Stakeholder Forum (SF) have contributed to shape the overall vision and to identify the main research and innovation areas listed above.

Fig. 2-4 include statistics on participants of the SF and TTs of the ESPREssO project. Overall, 44 stakeholders took part in these events, with key stakeholders participating in more than one event. The majority of stakeholders worked in the science domain (39%), followed by governmental institutions (25%). Non-profit organizations (18%) and the private sector (7%) were also present during the ESPREssO-events. Other stakeholder organizations included EU bodies (4%) and government/science institutions (7%) (Fig. 2).

Most of the stakeholders' organizations operated on an international/global scale (48%), closely followed by organizations acting at national level (43%). 7 % and 2% of the organizations were acting at European and regional level, respectively (Fig. 3).

About half of the stakeholders' organizations (43%) declared expertise in both DRR and CCA, while 48% indicated that they were exclusively focused on DRR. Only 9% of the participants declared an exclusive commitment to CCA (Fig. 4).

In addition, an online questionnaire[15] developed by the consortium was available from December 2017 to June 2018 and secured more than 100 responses. The intention was to identify gaps and issues by gathering opinions from a broader group of stakeholders involved in global and European initiatives in the domains of DRR and CCA.

Fig. 5-7 show the background, organisation and country of questionnaire respondents.

The background of stakeholders completing the online questionnaire was evenly distributed across the natural science, engineering and management/ social sciences sectors. (Fig. 5). Together these activities provide a range of perspectives when answering questions surrounding the three ESPREssO Challenges. The type of organisation within which responding stakeholders were based, was mainly institutional (47%) but also included a strong element from academia (38%). Private sector and NGOs were represented but at around 5% each (Fig. 6). 'Other' organisations included independent or freelance consultants and research institutes. Respondents reflected a wide range of countries, predominantly from within Europe. Germany had the largest percentage of responses, followed by Italy, UK and Denmark. Perspectives were also drawn from Jordan, Portugal, Sweden, Slovenia and Romania (Fig. 7).

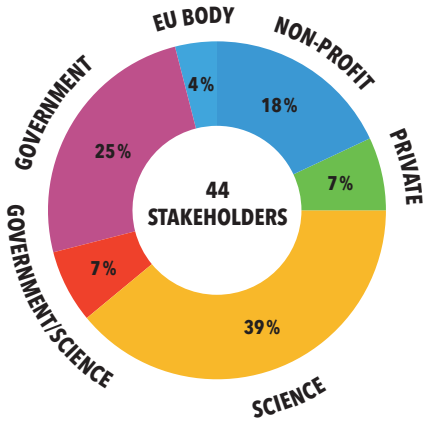

Figure 2: *Type of stakeholder's organization*

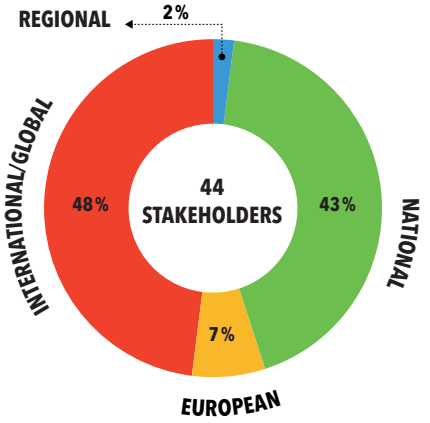

Figure 3: *Focus area of stakeholder's organizations*

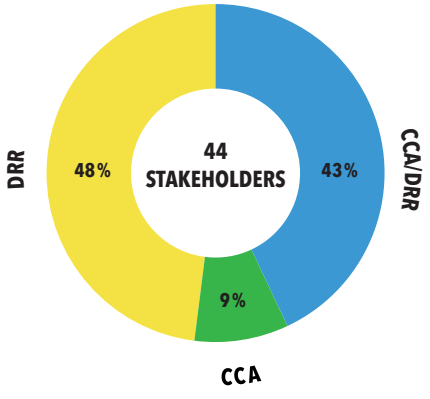

Figure 4: *Stakeholder's area of expertise*

15 https://www.surveymonkey.com/r/LVDBCXC

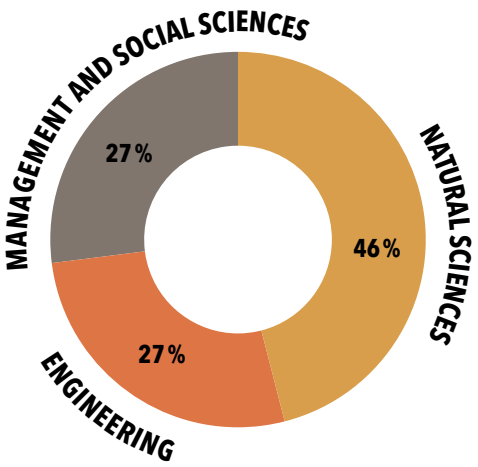

Figure 5: Questionnaire responses. Stakeholder background.

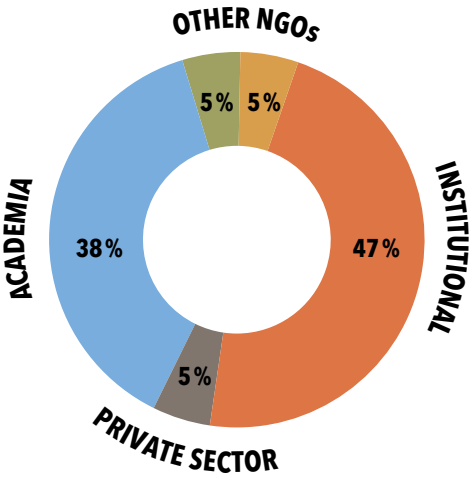

Figure 6: Questionnaire responses. Type of organisation.

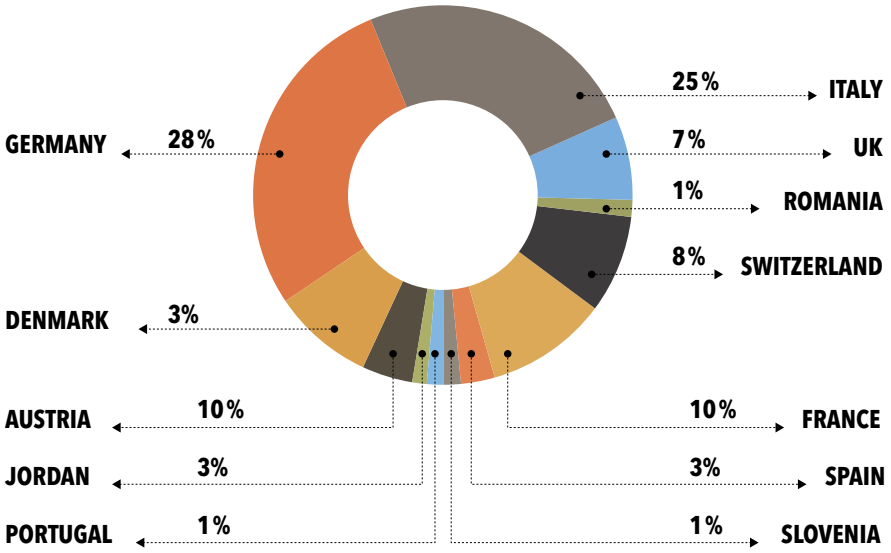

Figure 7: Questionnaire responses. Country of respondents. (n=100)

2 Framing the vision for future research on the Sendai priorities and recommendations

The Sendai Framework for Disaster Risk Reduction 2015-2030 is the global instrument for DRR. The Framework was adopted by the Third United Nations World Conference on Disaster Risk Reduction in 2015, continuing efforts of the Hyogo Framework for Action and identifies strategies for disaster risk.

Although the Sendai Framework is not intended to fill the gaps of the regulatory instruments, nor regulate how each individual sector or area needs to manage disaster risk (UNIDSR, 2015a), it presents guidance for the implementation of new and existing instruments, policies, programmes, guidelines and standards to support risk reduction strategies in relation to four priority areas[16]:

- Priority 1. Understanding disaster risk;
- Priority 2. Strengthening disaster risk governance to manage disaster risk;
- Priority 3. Investing in DRR for resilience[17];
- Priority 4. Enhancing disaster preparedness for effective response and to Build Back Better in recovery, rehabilitation and reconstruction.

The translation of the Sendai Framework into practical actions, as stressed within the Framework, should be done in coherence with other relevant post-2015 agendas and agreements including the 2030 Agenda for Sustainable Development[18], the Addis Ababa Action Agenda[19], the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (UNFCCC)[20], the World Humanitarian Summit[21], and the New Urban Agenda[22]. In this sense, the European Union Action Plan on the Sendai Framework[23], represents the opportunity to guide the implementation of the Sendai Framework within the context of EU policies. In addition, the European Commission is currently improving risk management capabilities in all the member countries through the EUCPM, with the aim of facilitating and enhancing cooperation among the Member States as well as strengthening preparedness, response and recovery against natural and man-made disasters.

The aim of this section is to align the findings of the ESPREssO project with the Sendai Framework, in order to address the relevant research and innovation areas to be fostered at EU level to successfully implement the framework in the next Horizon Europe Framework Programme.

Based on the four Sendai priorities listed above, each sub-section explores the opportunities emerging from an integrated vision of the Disaster Risk Management (DRM) cycle and its linkages with key overarching issues emerging from the networking activities of ESPREssO project within the SF and TTs, such as the integration of DRR and CCA, knowledge-based decision making, risk governance and management, cross-border and trans-national cooperation in DRM, resilience planning and urban design, communications and engagement with the general public to foster community resilience.

2.1 Understanding disaster risk

The understanding and the assessment of risks and their consequences is a critical and fundamental step towards the development of local, national and international strategies within all the phases of the DRM cycle. The availability of reliable scientific data and information to anticipate future disaster events and effectively support decision-making processes at all levels represents a global challenge for both the research community and governance institution. To meet this challenge, the Sendai Framework gives a comprehensive list of actions that will help to support of pre-disaster risk assessments and the implementation of appropriate preparedness and response measures. These mainly include actions at the national/ local and global/regional levels that address the issue of our knowledge of risks in all

16 https://www.unisdr.org/we/coordinate/sendai-framework
17 The definition of resilience, and its relation to risk, within ESPREssO, is in line with those provided by UNISDR (2017), as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management", and IPCC (2014) as "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation".
18 https://sustainabledevelopment.un.org/post2015/transformingourworld
19 https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=2051&menu=35
20 https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
21 https://www.agendaforhumanity.org/summit
22 http://habitat3.org/the-new-urban-agenda/
23 https://ec.europa.eu/echo/news/european-commission-launches-sendai-action-plan-disaster-risk-reduction_en

its dimensions and its changeable nature, through scientific/technological innovations, the promotion of appropriate risk-reducing investments, and supporting government officials and civil society as a whole.

The Framework introduces a new understanding of risk, based not only on records of past events but also on more precise forecasts and projections that reflect consideration of evolving trends and dynamics over time and space.

It is clear, therefore, that data collection (including, e.g., periodical updating, free availability, real time access) and analysis of expected impacts on specific sectors (e.g. effects on health, environment, cultural heritage, etc.) will foster a long-term perspective on resilience, and the development of efficient strategic and operational decision-support tools to improve the link between science outputs and decision making.

The understanding of risks depends also on a shared understanding of terms: the Framework calls for the development of a science-based terminology (UNISDR, 2015), expanding the risk concepts towards the emerging issues of CCA and resilience, preservation of vulnerable ecosystems, and multi-hazard disaster risk assessments. This entails the need to foster partnerships between different research sectors (e.g. climate science, social science, architecture/urban planning, etc.) and between scientists and policy makers, starting from a shared understanding of these key concepts and terms.

Understanding risk is also related to risk perception and acceptance from the standpoint of individuals, communities and governments. The communication of information with the different categories of end users and stakeholders entails issues related to the legal liability of information providers and the sometimes sensitive nature of data. Community-based organisations, NGOs and regional awareness campaigns have a key role in disseminating disaster risk information in all its dimensions, in order to create a culture of disaster prevention and build community resilience, in particular in relation to the memory of disaster losses and actions taken during past events. The attention to the geographical context is a fundamental aspect that should be reflected so that local knowledge and identity values are integrated within context-tailored governmental policies and strategies.

Emerging issues from ESPREssO

Advanced simulations and assessments
To support the decision-making processes and allow DRM choices to be based on the best available knowledge, risk and impact assessment approaches should be supported by evidence-based methods, including reliable probabilistic impact simulation and cost-benefit analyses with adequate spatial and temporal resolutions. Risk and impact assessment methods, based on accurate exposure data and adequate vulnerability curves for relevant vulnerability classes of elements at risk, should provide quantitative results with comparable metrics across different risks (especially in multi-hazard analyses) enabling and establishment of priorities. The effect of risk reduction actions - which should target the multi-hazard exposure of a given area where existing - needs to be integrated within risk assessment, so as to enable the comparison of alternative mitigation and/or adaptation measures in terms of avoided impacts and enhancement of long-term resilience increase. Risk and impact assessments should not be just limited to consideration of knowledge derived from the most recent event or events that have occurred in a given area (although these do represent an essential source of information that supports the provision of quantitative results). These assessments should also support the development of DRM plans that include consideration of high and low impact scenarios (including those that would result in the failure of preventive measures), their probability of occurrence, and the expected impacts on relevant sectors and operations. The evolving perspective, shifting from the management of disasters to the management of risks, makes evident how risk assessments based mainly on the understanding of hazards rather than on vulnerabilities of selected elements at risk (including both physical, social and psychological forms of vulnerability) are not sufficient to address the societal challenges linked to future disasters and climate change impacts. Therefore, consistent and comprehensive ways to assess vulnerability, and especially time-dependent vulnerabilities, are also needed.

Interdisciplinary research
A complete integration of climate change and natural hazards domains, thus bridging DRR and CCA perspectives, is required, taking advantage of the improvement and greater availability of scientific information in these fields (e.g. online climate services).

Risk assessment studies and outputs (reports, guidelines, operational frameworks etc.), in line with the Paris Agreement, should also include consideration of climate change adaptation strategies so as to support the implementation of long-term strategies also linked to emission reduction and energy efficiency.
As encouraged in the Sendai Framework, more investments in science and technology are needed, including the mobilization of scientific networks and "risk partnerships" between diverse fields, including climate change studies. This will impact firstly on region-dependent hazard assessments (including the potential shift in the frequency and magnitude of occurrence of different hazards), and then on vulnerability and changes in exposure. Within an integrated DRR-CCA perspective, risk knowledge should then strengthen interdisciplinary activities, engaging interconnected scientific fields such as geophysics and geology, climate science and meteorology, engineering and social sciences. Multidisciplinary considerations and methods integrated into the required assessments can emphasize the "weight" of central factors such as globalization, social justice and human rights, quality of life, social and economic constraints (e.g. immigration, food security, terrorism, media coverage etc.), the overexploitation of resources, epidemics and pandemics. In this sense, the role of sectorial expertise in various fields (e.g. human health, cultural heritage, critical infrastructures etc.) needs to be strengthened to add value to a comprehensive evaluation of risks and the related damage to human society (both tangible and intangible elements) as a whole.

Data management and information update
To enhance the understanding of risk, risk knowledge needs to include a periodic updating of assessments, in relation to the improvement of available datasets and models, in support of the evolving decision-making needs in the field of policy and planning. The determination of appropriate baseline scenarios and corresponding risk thresholds, as well as effective use of the considerable amount of data potentially available (e.g. from earth observations, historic databases, academic and business data repositories etc.) and the impact of urban/town planning and design strategies with regards to DRM, are all essential aspects to incorporate. Advanced methods to integrate impact information into forecasts, early warning systems, and near-real-time impact simulations combined with data-farming approaches, should be further investigated, as well as specific and shared templates to collaboratively collect information on events in the EU and beyond. Rapid integrated assessments of disaster losses could provide valuable insights for holistic post-disaster aid, response and recovery needs.

The limited availability of scientific information and results also depends on uncertainties of scientific assumptions, as well as reliability of information providers and access limitations due to intellectual property rights (e.g. on models and data). Key to improving the understanding of risk is the need for researchers to acknowledge the complexity of the knowledge process, especially with regard to the sometimes-substantial level of uncertainty associated with such knowledge. This in turns requires careful thought as to how knowledge can be translated into actionable results for decision makers, including identifying new ways to communicate with politicians and the general public, all the while acknowledging and recognizing the associated uncertainties. The critical aspects are the translation of results into relevant, usable, credible and legitimate information that supports decision-making and the resulting decisions.

Harmonised data, protocols and procedures
Efforts are being made by EU Member States to improve the coherence and transparency of risk assessments undertaken at the national level, also with the view of making them more comparable between countries. However, the lack of a common methodology and the presence of different standards for data collection and disaster risk/impact analyses and assessments (i.e. hazard, exposure, vulnerability, impact on communities and built/natural environment) represent a weakness in the whole process. For this reason, further reflection should include how to develop harmonized protocols and procedures and how to standardize the assessment thresholds among countries. In this sense, the effort in developing appropriate ISO standards (e.g. ISO 14090, 14091 and 14092) is a critical step. Sharing of experiences, cross-national validation and integration of scientific methods and operative strategies, implementation of common risk/impact scenario databases between countries is also needed to acquire a more effective knowledge of cross-border risks.

Co-creation of knowledge
Understanding risk is not only related to scientific and technological advancements. Researchers and knowledge providers can fill gaps but only the effective co-creation

of knowledge with practitioners, affected communities and businesses can ensure that the knowledge will be relevant and applicable (EEA, 2016).

A systemic approach tackling economic, social and environmental dimensions within an integrated perspective is required to streamline challenge-driven, solutions-oriented, trans-disciplinary research and innovation pathways. This implies that technology, business models and economic organisation, finance, governance and regulation as well as creativity, skills and social innovation, are involved to define innovative methods for the co-creation of knowledge and co-delivery of outcomes with economic, industrial and research actors, public authorities and communities.

In this context, the role of behavioural and social sciences is important to understand the implication of past disaster events on decision-makers choices and on cultural changes, as well as on relational and emotional aspects among the citizens.

A joint co-creation approach would also allow a greater reflection upon the issues of legal responsibilities, responsibility allocation and sharing in risk management, while introducing participatory processes and community-based approaches along the entire cycle of emergency, from long-term preparedness to post-event recovery. These processes should co-create knowledge by integrating the perspectives of and information provided by different stakeholders in the design of e.g. resilience, emergency and recovery planning.

The ongoing initiatives from the JRC, the DRMKC[24] and the EEA[25] need to be supported to identify new pathways and networks to disseminate academic research findings and innovations to the practitioners and to the general public, being aware not to identify preferential and auto-referential paths, but rather to set out to emphasise the plurality of the required participation.

Communication and dissemination platforms
Increased dialogue and cooperation between scientific and technological communities, stakeholders and policymakers, NGOs and community-based organizations can contribute to the sharing and building-up of the knowledge of hazards and related risks, for a comprehensive awareness of the risk at all levels. The development of a "risk memory" and the implementation of "lessons learnt" into policy and governance actions, both at national and transnational levels, can extend the knowledge of disaster risks and consequences on society as a whole. Scientists and policy makers should communicate their knowledge in order to contribute to build community resilience and a risk-informed society. Communication should be conducted by means of formal and informal education activities (including the understanding of probability and uncertainties in science), through community and bottom-up mobilization, community-based organizations, NGOs, traditional and social media, mobile technologies, etc. A simplified and more accessible terminology to fill the gap between science and policy-makers is needed, as well as an effective use of technology to enhance data connection and availability[26]. This in turn calls for investigation into new ways of communicating and explaining complex issues in a more comprehensible way that appropriately reflect the needs and capabilities of different categories of users. This should include e.g., the presence of facilitating actors, institutions or platforms, which enable a more efficient, productive, and satisfying transfer of knowledge from the scientific or academic domain to policy-makers and communities.

2.2 Strengthening risk governance to manage disaster risk

The Sendai Framework introduces various elements to strengthen DRR governance in its institutional and participatory aspects at national and local levels. This would involve improving coherence and collaboration across institutions and public bodies, by defining laws, regulations, and responsibilities. Guidance is provided on how to strengthen the international cooperation mechanisms, recognizing the importance of existing regional and sub-regional strategies and plans (UNISDR, 2015a).

Following the Sendai Framework, each State is to define its DRR strategy based on the knowledge of vulnerabilities, the assessment of technical, administrative and financial capacity of institutions to deal with risks, as well as addressing specific regional and local conditions. Public and private sectors can improve risk governance by establishing partnerships in research and innovation, which would lead to improvements in risk modelling, knowledge management and information sharing, and the development of normative

24 https://ec.europa.eu/jrc/en/network-bureau/disaster-risk-management-knowledge-centre
25 https://www.eea.europa.eu
26 https://www.placard-network.eu/words-matter-using-language-technology-to-better-inform-the-cca-drr-communities

instruments and quality standards. These in turn would allow the more comprehensive and relevant formulation of policies and plans, while also touching upon risk education, and the improved resilience of critical services, facilities and infrastructures. Such improved risk governance to manage disaster risk needs to be focused on the abovementioned multi-hazard and multi-sector understanding of risk, so to avoid "siloed" science and policy approaches in DRM.

Emerging issues from ESPREssO

Knowledge-based decision-making
There is a general recognition of the role of science and technology in informing policy makers. This requires expertise in risk assessment and communication in public governance institutions, private companies and NGOs, which is broadly acknowledged to be a priority area for improving risk governance. It is also recognised that horizontal integration with the scientific community requires the involvement of research agencies in developing risk-informed decision-making processes and platforms, suitable structures and smart management cockpits. The role of science should be to appropriately engage in and promote knowledge sharing (from basic and applied research) with the government institutions, defining provisions to avoid conflict of interest, avoiding overlapping of accountabilities and tasks, which has been demonstrated to be ineffective and even dangerous.

Multi-risk and multi-level governance frameworks shifting from a single (siloed) risk focus to embracing a multi-risk approach when working with technical and political authorities should be co-developed and co-evaluated.

Whole community governance
Directly linked with the knowledge of risk, new risk partnerships that bring together knowledge and skills from different stakeholders and create links with the private or industry sectors are emerging as a preferred approach for engagement in improving risk assessments at various scales, by bringing together skills from different stakeholders and creating links with the private or industry sector. A proactive approach that includes different stakeholders, in line with their skills and resources (including e.g. multi-stakeholder platforms, technical tables, think tanks etc.), provides means for active engagement with authorities for the implementation of national and local strategies and plans for DRR and CCA.

A whole-community approach, as outlined in the Sendai Framework, requires the inclusion of different stakeholders and the participation of society as a whole, thereby enabling the proper definition of responsibilities and rights across stakeholders and institutions. Despite several examples of engagement with citizens in the field of DRR and CCA, effective and recognized practices and rules for community-based institutions, representing individual citizens, households, associations, etc. in supporting response plans are being developed only recently, including deliberative democracy initiatives. Since the public's interest in disasters is high when events occur, but dwindles quickly thereafter, it is important to develop effective strategies for communication and awareness raising, ensuring that the public correctly understands and interprets any provided information and the need for action. There is a need to engage and support politicians in promoting such awareness campaigns and creating a culture of disaster prevention, even if such endeavours extend beyond the next election cycle.

Synergies between policies: DRR, CCA and Sustainable Development Goals (SDGs)
At global and EU level, further integration across DRR, CCA and SDGs policies is needed to improve the coherence between the associated frameworks. Divergent government structures for both CCA and DRR are widely acknowledged as one of the major barriers to integration in many countries and in the EU. Divergent policies by separate institutions create several issues, including funding discrepancies, inter-agency rivalries, confusion among stakeholders (as a result of different terminology for example) and so on. Recent initiatives conducted at EU level, such as the DRMKC Science for DRM 2017 report [27], the EEA 2017 report on CCA and DRR [28], the S&T Roadmap for implementation of the Sendai Framework [29] and the resilience agenda [30] have provided a framework for action both globally and at the national level. The challenge is now for actions globally and nationally to build on this alignment and deliver a post-2015 actions that improve synergies, including communications. One opportunity can be the linkage between the two cycles of DRM and adaptation, embedding climate risk management along the cycle [31].

27 https://ec.europa.eu/jrc/en/publication/science-disaster-risk-management-2017-knowing-better-and-losing-less
28 https://www.eea.europa.eu/publications/climate-change-adaptation-and-disaster
29 https://www.preventionweb.net/files/45270_unisdrscienceandtechnologyroadmap.pdf
30 https://ec.europa.eu/europeaid/node/1418_es; https://ec.europa.eu/europeaid/sites/devco/files/european-consensus-on-development-final-20170626_en.pdf
31 https://www.placard-network.eu/joining-forces-cca-drr-workshop

The critical issues and benefits arising from the establishment of high-level institutions dealing with both DRR and CCA, in a multi-risk governance perspective, should be investigated. Benefits and challenges related to options for enhancing cooperation and coherence at the international and national levels should be investigated recognising that the aim is to break down existing silos while avoiding establishing complex and inflexible governance mechanisms. Hence the cross-cutting issues bridging DRR and CCA need effective collaboration and overarching coordination that enables institutional barriers to be overcome.

At the national and local levels, analysis of the collected data suggests that for many countries there is a need for a complete institutional overhaul and restructuring. This requirement reflects that there is a lack of sufficient coordination between DRR and CCA, not only at the national level, but also between levels of government (national, regional, local and municipal). There is a need to clarify the roles of local and governmental actors (e.g. ministry of interior and ministry of environment) and to increase the participation of local stakeholders and the general public in the decision-making process.

Cities should play a key role in integrating DRR and CCA[32]. Science-practice-policy alliances can support the cities' technical capacity in regions where it is currently lacking, also allowing further horizontal links between urban contexts in a knowledge-sharing perspective.

Transboundary cooperation
Considering a medium-term perspective for the EU, the cooperation at the scientific and administrative levels between the national and international institutions and authorities involved in the field of natural hazard management must be intensified and harmonized. Transnational and multinational disaster risk governance requires cross-regional, transboundary, bilateral and cross-sector agreements, including information sharing and aligned communication. This is especially the case considering the implications of a changing climate and what that means for extreme events. There is a need to reach consistent policies and flexibility between countries, developing bilateral agreements on common problems. Coordination between governments at the international level can allow appropriately tailored policies and strategies for each context, considering the specific features of different places and preserving the sovereignty when it comes to the management of a transboundary threat.

The positive examples of the EU macro-regional strategies[33] (Danube[34], Baltic[35], Alps[36], Adriatic-Ionian[37]), should serve as a basis to improve the transnational cooperation within a shared EU perspective. Peer reviews, international enquiries and exercises, intended as governance tools for the exchange of good practices, needs to be harmonized across the EU, while also considering the needed strengthening of the EUCPM. In turn, the EUCPM has to adapt to the transnational nature of disasters, encouraging knowledge exchange between countries as a way to build the future implementation of the EU's risk management policies and strategies.

Improved legal frameworks
The definition of clearer responsibilities across all relevant institutions (especially concerning early warnings, risk assessment, building regulations, etc.) requires enhancing the systemic efficiency and understanding of roles, rights, and duties of all actors involved in risk governance and management.

In the countries where this issue is not already taken into account, decision-makers, scientists, technicians, and operational bodies need to be safeguarded from the legal and economic consequences of their actions under emergency conditions, identifying adequate legal frameworks that cover the existing issues linked to false alarms, non-robust forecasts, for example. Informed risk governance also requires consultation with representatives of civil society groups, which may be able to "indirectly" influence the decision-making process. These groups should be able to cooperate through ad hoc legal frameworks, thus enabling a continuous consultation with the general public aimed at raising a new culture based on resilience and risk reduction and based on the community engagement, awareness and empowerment on political choices and procedures in the fields of DRR, CCA and DRM.

2.3 Investing in DRR for resilence

This priority focuses on the topic of investments in DRR and CCA fields, indicating possible actions to give consistency and coordination to policies and programmes. With this, the Sendai Framework does not intend to propose precise policies on economic and/or environmental issues.

32 http://uccrn.org/files/2015/12/ARC3-2-web.pdf
33 http://ec.europa.eu/regional_policy/it/policy/cooperation/macro-regional-strategies
34 http://www.interreg-danube.eu
35 https://www.interreg-baltic.eu
36 http://www.alpine-space.eu
37 http://www.adrioninterreg.eu

Rather, the Framework aims at stressing the importance of economic, social and cultural investments in building disaster resilience (UNISDR, 2015a).

Despite the step change in the Sendai Framework from a culture of response to a culture of prevention, an unbalance in investments for DRR and DRM by EU governments still exists. The Framework makes a strong call for investing more resources into resilience, ensuring that risk-informed investments, by both the public and private sectors, are adequately implemented, and that DRR measures are integrated into the appropriate financial and fiscal instruments (UNISDR, 2015a). Resilience investments should go beyond 'hard' infrastructure (i.e. physical structures such as dikes, dams and hazard-resistant buildings), but systematically consider 'soft' infrastructure such as nature-based solutions, education, emergency and support networks and the so-called "safety net". This integration of measures will contribute to saving lives and reducing economic losses, while improving local and national economic growth and job creation. Incentives and financial benefits focusing on DRR should encompass key sectors such as land use, urban planning, building codes, and the environmental management of resources, including the promotion of quality standards.

The Framework puts an important emphasis on critical infrastructure and facilities to be built "better from the start", including the reinforcement of building codes and maintenance measures, and an improved resilience of health system, educational facilities and productive assets. This aspect is also linked with the preservation and enhancement of cultural heritage and the sustainable management of ecosystem as part of an overall strategy to build resilience of communities and cities, integrating the strengthening of related EU industry sectors, such as tourism, in a DRM and CCA perspective.

Emerging issues from ESPREssO

Funding knowledge
The assessment and anticipation of the economic and social dimension of disasters (e.g. cost-benefits and multi-criteria analyses), opens new frontiers for developing financial instruments supportive and informed by the preliminary knowledge about risk and potential impacts (UNISDR, 2015a). Non-structural investments are needed, and should be addressed to the integrated monitoring, forecasting and early warning systems and preventive measures and promoting investments to reduce uncertainties, taking into account both identified trends and unexpected events. The perceived large potential for external contributions by private stakeholders, including insurance sector, public-private partnerships, volunteer groups, is still not adequately investigated, and the benefits coming from the engagement of industry, technological innovation and other sources of expertise need to be further explored and articulated.

Funding implementation
Investments for structural prevention plans and interventions are needed to reduce disaster risk and should be programmed in the context of long-term perspectives. In some cases, public buildings (e.g. schools, hospitals, public services) and strategic infrastructures are built and maintained by private owners. In these cases, coordinated efforts are needed to ensure their operational continuity and resilience, as well as ensuring a clear framework of responsibilities to provide for their functioning under emergency conditions.

Natural resources and ecosystem management through novel land use planning in urban and rural areas, as well as new innovative ecosystem-based solutions, represent a key area of action and need major investments both in terms of research and practice from both the public and private sectors. These investments in DRR need to be channelled towards a multi-disciplinary research approach, including through the engagement of diverse sectorial expertise from across all relevant fields, and at the same time considering the practical application of new methodologies.

Funding multi-risk resilience
National and local governments can foster private investments by introducing improved building codes and construction regulations that are able to deliver favourable returns on investments by integrating DRR (e.g. structural improvements), CCA (e.g. social, economic and environmental quality) – both linked to "building better" - and climate change mitigation (e.g. energy efficiency), based on the existing sectorial incentives.

In this sense, greater efficiency of funding mechanisms is needed to bring together funding flows for both DRR and CCA, favouring and privileging redevelopment, maintenance, response and recovery measures designed in a multi-risk perspective. There is a general lack of funding for combined CCA-DRR activities including at EU and global levels, therefore devoted research projects that specifically address cost-effective strategies synergistically tackling DRR and CCA should be encouraged. Research into investment strategies for resilience should take into consideration the multiple benefits influencing daily the lives of

communities (e.g. healthcare, heritage and culture protection, energy services etc.).

Funding country-specific priorities
The uneven distribution of resources at regional level within EU Member States, often linked to the lack of capacity of some regions in attracting and managing funds, is a major barrier to the integration of CCA and DRR. Municipalities do not always have the resources, knowledge and practices required to integrate these diverse fields or to develop an understanding of the nature of risks in a climate change perspective. Local governments should be supported by EU agencies and national authorities in the identification of funding priorities, the assignment of appropriate budgets and cost-benefit assessments over time (including maintenance). Further investment in capacity building across institutions (at all levels) is needed and how to start this process should be investigated.

Funding international priorities
At the international level, there is a need for consistency and balance among investment funds (e.g. European Regional Development Funds[38], NGOs, international funders) and for a more appropriate balance among funding across the different phases of DRM cycle, including a special focus on preparedness and recovery. A thorough evaluation and assessment of funding and the impact of implemented actions is constantly required to guarantee effective distribution and targeting. Transnational cooperation through agreements could make the creation of adequate budgets for improved risk management practices possible, e.g. by combining many smaller budgets.

Under diverse agreement types, multilateral cooperation and financial assistance among countries are already established. These can be further improved through a more precise operational framework where the contributions are specifically targeted to implement the needed actions that considers the specific requirements of a country/region (e.g. sharing knowledge, technical cooperation, technology transfer, training of experts etc.).

Funding resilience awareness
Major investments are needed to increase community resilience and should include, at all levels, public risk awareness campaigns and educational programmes (not only in schools, but also in workplaces, sport environments etc.). Societal and cultural diversity across the EU is a valuable resource, potentially bringing together a range of options, skills, viewpoints and expertise that will contribute greatly to the strengthening of resilience and help to ensure democratic governance. New research investments should also investigate how to build resilience and local ownership, while including a human-right-based approach considering the diversity of vulnerable groups (e.g., refugees, migrants) through engaging them as vital participants in the development of DRR strategies.

2.4 Enhancing disaster preparedness for effective responsive and Build Back Better in recovery, rehabilitation and reconstruction

The topic of preparedness has huge implications on the entire DRM cycle, given its recognized potential for reducing losses and increasing the operational capacity of responders, along with significant impacts on the emergency planning and management phases. Additionally, this topic involves organizational and technological aspects, ranging from the definition of command and control levels, to the availability of simulation, monitoring and early warning systems, coupled with effective communication means, especially in the context of a behavioural approach. Key aspects such as the need for real time or near-real-time assessments, which should include multi-hazard and multi-sectorial evaluations, including cascading effects, are identified.

Build Back Better, or the need to prepare for recovery, rehabilitation and reconstruction to increase resilience (UNISDR, 2015a), represents a significant breakthrough concept introduced by the Sendai Framework. Post-disaster reconstruction experiences have revealed a variety of best and worst case scenarios worldwide, thus entailing the need to translate into strategies and policy actions the core principles to be adopted to introduce resilience principles consistent with enhancing resilience into the post-event reconstruction planning and design measures.

The need to include such principles into long term development plans requires strong institutional coordination across sectors and levels of administration, while also considering the declared objective of integrating DRR measures into the restoration of not only physical infrastructure, but also of societal systems and the revitalization of livelihoods, economies and the environment.

Emerging issues from ESPREssO

Widespread Build Back Better principles
The widespread adoption of Build Back Better principles requires technical-scientific and political-operational capacity to be strengthened in order to consolidate the existing knowledge and design methods. This must

38 http://ec.europa.eu/regional_policy/en/funding/erdf/

be done while developing and implementing adequate regulations and building codes to define performance benchmarks for resilient construction. Resilient cities, buildings and infrastructure require different design values to be introduced, taking into account emerging risks such as those induced by climate change. Different sectoral technical and socio-technical expertise linked to DRR and CAA (e.g. human health, cultural heritage, security and safety, climate agencies, etc.), need to be engaged, as well as the professional sector expertise (planners, architects, civil engineers, building actors, geologists and geophysicists) to develop and explore new and innovative solutions. The involvement of sectorial expertise in best/worst practice review process, including post-event damage assessment and the evaluation of damage mechanisms, should be engaged in developing and evaluating national DRR strategies, providing an additional base upon which to implement new standards and regulations for Build Back Better and to allow greater flexibility and adaptability of measures and actions in response to climate change and to expected disasters caused by natural events.

Evolution of early warning systems
Early warning in real and near-real time and associated alert systems also need to be developed for both national and transnational circumstances. This implies not only the improvement of existing monitoring networks and hazard/risk/impact modelling systems but also the complete implementation of the preparedness measures that may be carried out on critical infrastructure and services following alerts. However, accompanying such intelligent measures are those that address implications concerning liability and accountability of information communicated to policy makers and then to the general public. Maintaining the continuity of critical infrastructure, which ensures the provision of essential services to the public under emergency conditions, is one of the main challenges in the context of both preparedness and Build Back Better. At the governance level, it is necessary to enhance cooperation between public authorities, operators, and other relevant stakeholders in such a way as to build up and enhance the resilience of infrastructure systems and to stimulate public-private investments in critical facilities and basic services, provided that many critical infrastructures play a key role in supporting response and emergency operations.

Transboundary coordination and cooperation
At the international level, the emergency response system involves cooperation beyond the governmental level. Developing responses to both natural and anthropogenic disasters has seen a wide array of networks established in which sub-governmental as well as non-governmental actors play a significant role, either in response to explicit requests, or through their own initiative. Different EU directives and policies have aimed at strengthening transboundary crisis management (e.g. EUCPM), especially with regards to flooding, where clear regulations and agreements are in place in most of the regions potentially affected.

The diverse capacities and specialized knowledge available from national civil protection actors are relevant and should be harmonized across the countries by further deploying, for instance, the sharing of good practices and common training exercises.

In the operational phase, synergies and cooperation among and with NGOs and volunteering organizations should include representatives from coordinating institutions at the EU, national and local level, allowing the experimenting of new models of coordination.

Any policy legislation on evacuation should include a full consideration of human rights and local knowledge, and be supported by training exercises, the establishment of voluntary groups, and the continuous updating of emergency planning outputs.

Improved communication to general public
Difficulties communicating to the public during the preparedness and response phases has also been identified as a key issue, requiring the consideration of legal aspects, along with investigations into innovative forms and tools that will enable the more effective sharing of information. On the one side, the legal consequences of risk communication need to be addressed, including critical issues such as the development of effective communication protocols e.g. warning communication chain; role, tasks and responsibilities of science advisors and the collateral effects of practitioners' defensive behaviours (e.g. when avoidance of personal liability clash with the protection of vulnerable communities or the transparency of decision making). On the other side, there are issues of scepticism around online information and news due to a lack of engagement with social media by public authorities. A lack of public awareness when preparing for emergency response in relation to early warning forecasts has been observed, and a comprehensive strategy for reaching the public with the proper messages throughout the DRM cycle require a specific and clearly understandable plan.

3 Natural hazards, DRR and CCA: research and innovation priorities in the EU

This section provides a brief description of the main natural hazards that affect EU territories and the related research activities outlined by the EU Commission Staff Working Document 176: Overview of Natural and Man-made Disaster Risks the European Union May Face [39] (henceforth referred to as the Overview). This is complemented with findings from the recent reports issued by EEA [40] (2017), DRMKC [41] (2017) and UNISDR [42] (2016).

The National Risk Assessments (NRAs) from the 28 EU Member States and the six non-EU countries participating in the EUCPM are based on the European Commission Guidelines for Risk Assessment and Mapping, providing a comprehensive and cross-sectoral overview to be periodically updated, reflecting the dynamic nature of disaster risks.

The analysis of NRAs highlights the presence of different assessment methods and governance approaches, as well as a number of significant commonalities. Risk assessment, vulnerability analysis and emergency management need to be further harmonised for all kinds of natural hazards, supporting the Sendai Framework and EUCPM objectives in promoting joint activities in relation to regional priorities. Initiatives addressing regional and multi-national risk assessment and management should be further exploited and expanded, e.g., through the INTERREG [43] instruments.

The impact of natural hazards affecting European countries is increasing. Indeed, growing populations (hence greater exposure), and modern society's increasing interconnectedness, lead to the increased likelihood of cascading effects disrupting livelihoods, especially with respect to the impact on critical infrastructure and service networks. While natural hazards have often been considered independently, there must be an enhanced awareness (as specified within the Sendai Framework and various EU calls) of the potential linkages between events, for example, cascading events or the increased likelihood of certain events due to the occurrence of others (e.g. forest fires during heat-waves and drought; landslides triggered by heavy rains), as without this our understanding and ability to respond may be constrained as response resources and capacities are limited. Furthermore, long-lasting processes such as climate change and desertification, urban migration and land-use change, can for example exacerbate impacts on built environment, critical infrastructure and society as a whole.

According to the Global Risk Report 2018 [44], natural hazards are among the major risks at global scale in terms of likelihood and potential impact. In particular, extreme weather events are considered to have the highest impact and the highest likelihood within the global risk landscape, which includes economic, environmental, geopolitical, societal and technological risks.

39 Commission staff working document 176 final 23/05/2017 Overview of Natural and Man-made Disaster Risks the European Union may face http://ec.europa.eu/echo/sites/echo-site/files/swd_2017_176_overview_of_risks_2.pdf
40 https://www.eea.europa.eu/publications/climate-change-adaptation-and-disaster
41 https://ec.europa.eu/jrc/en/publication/science-disaster-risk-management-2017-knowing-better-and-losing-less
42 https://www.preventionweb.net/files/45270_unisdrscienceandtechnologyroadmap.pdf
43 https://www.interregeurope.eu/
44 World Economic Forum, The Global Risks Report 2018. 13th Edition, Geneva.

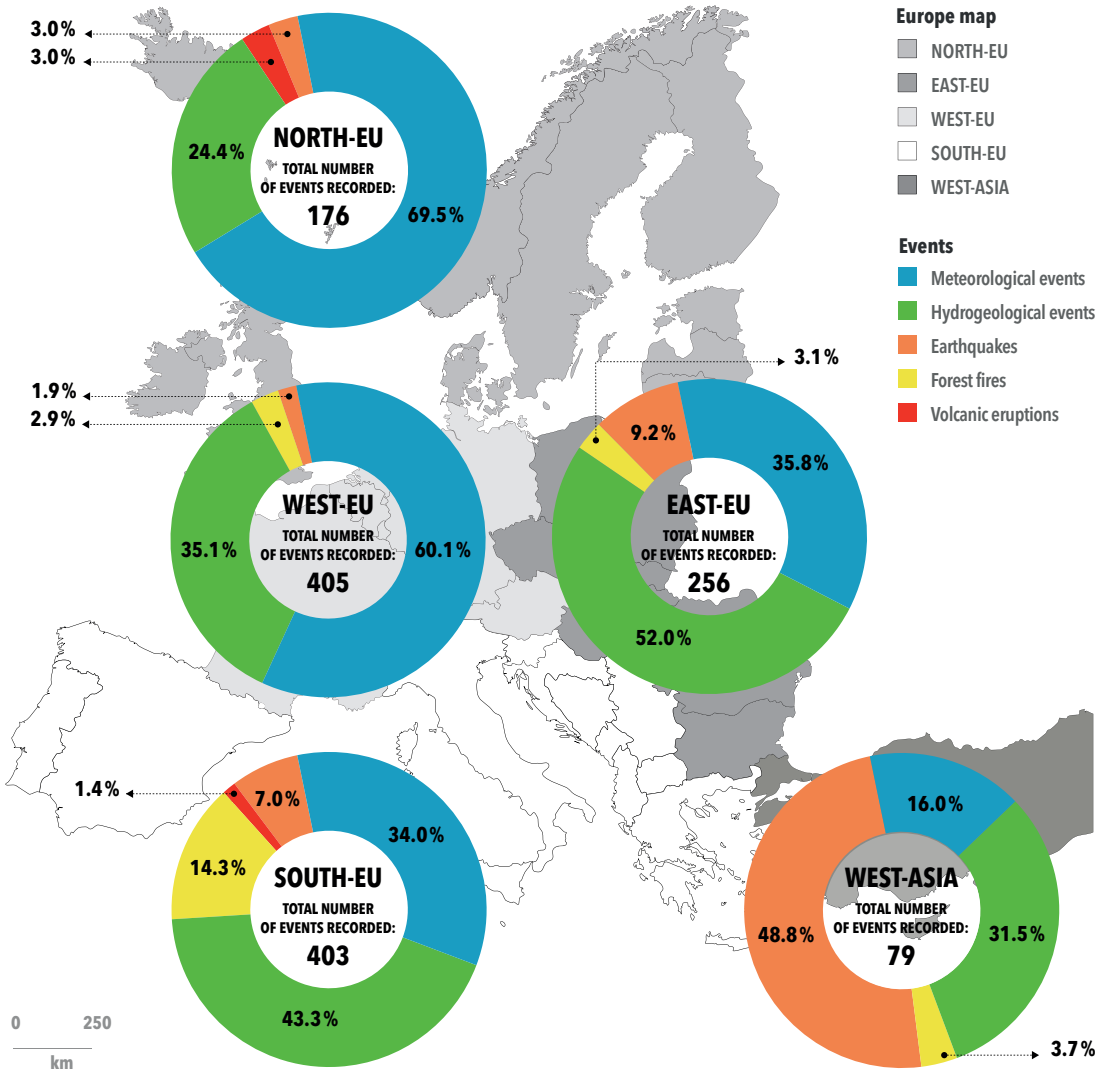

Figure 8: *Map of natural events recorded in the EM-DAT catalogue and grouped according to the geography of Europe. Events (total 1402) are from 1903 (earthquakes), 1906 (volcanic and hydrogeological), 1928 (meteorological), 1949 (forest fires). Events are not recorded based on intensity and losses. Source: EM-DAT catalogue, EEA.*

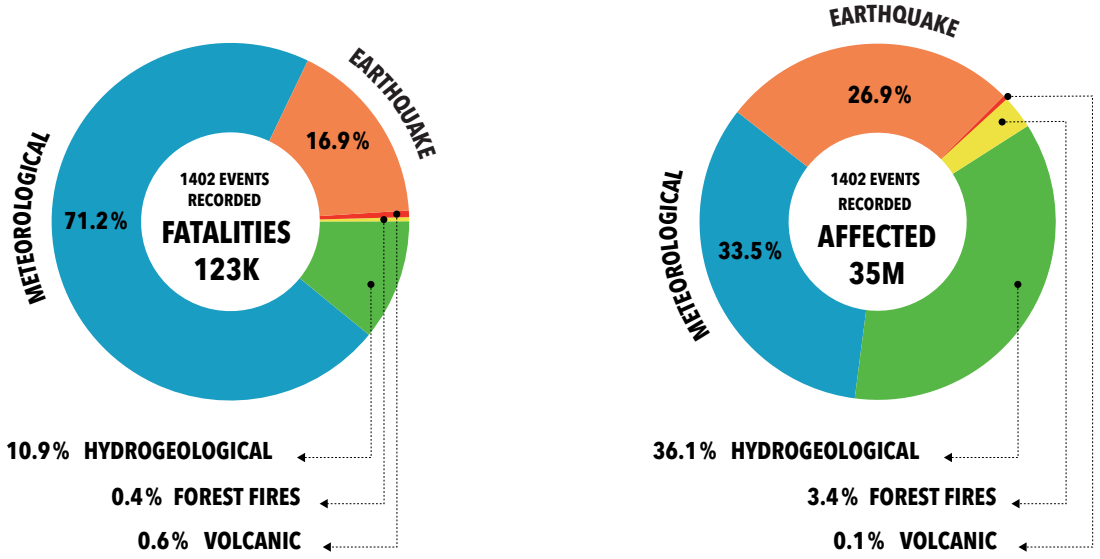

Figure 9: *Percentage distribution of fatalities and affected people (deaths, homeless, injured) for each type of natural event considered (1402 events recorded from 1903 - 2018).*

3.1 Extreme weather events

Extreme meteorological events are considered important threats in most EU countries and the effects of climate change already being felt have made this even more apparent, in particular due to the interdependences with other natural events (e.g. flooding, drought and coastal inundation). At the same time, slow onset events, such as increasing temperature and sea level rise increase existing risk conditions while introducing new risks. As climate change is increasing temperatures and affecting seasonal rainfall distribution patterns, Europe has seen a large increase in temperature and precipitation extremes in some regions.

Despite most of Europe being rich in water resources, there is a high likelihood of water scarcity, drought and heatwaves, mostly in the Mediterranean area. The heatwave of 2003 affected over 100 million people in North-West and South-West Europe (most impacted countries were France, Italy and Portugal), with the estimated fatalities in the order of thousands to tens of thousands. In 2011 and 2012, droughts affected southern, western and even some northern parts of Europe, and since 2015 there have been record-breaking temperatures with severe droughts in France, Benelux, Germany, Hungary, the Czech Republic, Poland, northern Italy, and northern Spain, leading to restrictions on civil and industrial uses of water. This trend has been dramatically confirmed in 2018, where extremely high summer temperatures and heat waves hit large parts of Europe, with severe impacts also in the northern regions, coupled with widespread drought conditions that triggered extensive forest fires (e.g. in Greece and Sweden).

Northern Europe is also more exposed to winter storms and storm surges coming from the Atlantic region, a threat that gradually lessens towards southeast Europe. Some of the main risks associated with extreme precipitation in the EU are landslides, coastal erosion and saltwater intrusion, which may be exacerbated by sea level rise due to the climate change.

According to the NRAs, extreme weather events are recognized to be a moderate to high level risk, having effects on infrastructure and in some case triggering cascading effects such as landslides and wildfires. Specific impacts are observed in relation to human health (e.g. winter storms in Finland, heat waves in almost all regions) and local businesses/ identity (e.g. extreme weather impacting the tourism industry in Malta). Cross-border issues on extreme weather have not been defined, but it is recognized that such events can affect an extended region covering more than one country, directly and indirectly. For example, the potential difficulties posed by lower water levels in France during drought periods poses potential challenges to the operation nuclear power stations.

European research and capacity-building projects have focused in particular on extreme events on coastal regions (for example, MICORE[45], PEARL[46], RISC-KIT[47], RISES-AM[48], SAVEMEDCOASTS[49]). As an example, the SIAM[50] project in Portugal has contributed to the identification of a core set of socio-economic and biophysical impacts based on climate projections investigating sectors such as fishery, forestry and biodiversity, health, water resources, agriculture, coastal zones and energy.

Main research gaps and needs

- Advancement of (transboundary) forecasting systems and their application within emergency planning and response capacity improvements.
- Understanding the evolving nature of hazards under climate change (new events such as heat waves in northern regions, 'medicanes' etc.).
- Potential cascading effects of extreme weather events in a climate change perspective (e.g. potential of extreme precipitation events in triggering landslides and hydrogeological phenomena).
- More detailed climate projections and socio-economic scenarios to support impact assessment on diverse sectors and improve DRR and CCA action on the regional to local scale.
- Monitoring of direct and indirect impacts of extreme weather events and corresponding data, development of databases at national and European scale to have a sound overview about impacts and hotspots and decide upon future investment, considering climate change trends and signals.
- Linkages and synergies between the DRM cycle and the adaptation cycle to improve

45 http://www.micore.eu/
46 http://www.pearl-fp7.eu/
47 http://www.risckit.eu/np4/home.html
48 https://climate-adapt.eea.europa.eu/knowledge/adaptation-information/research-projects/rises-am/RISES-AM
49 http://www.savemedcoasts.eu/index.php
50 https://climate-adapt.eea.europa.eu/metadata/publications/climate-change-in-portugal-scenarios-impacts-and-adaptation-measures-siam

coherence between CCA and DRR.
- Further support exchanges between actors along the DRR/DRM and CCA cycles, especially in the phases of prevention and preparedness, seizing the best from knowledge in both fields.

- Comprehensive analyses of heat wave effects on different sectors and interactions of effects for planning of resilience measures.

- Implications of climate change for the efficacy of emergency services both in the context of preparedness and response capabilities, including how to Build Back Better these capabilities.

- Exploiting the added value of nature-based solutions for DRR in relation to the different types of hazard.

- Enhancing climate services in support of operational and strategic decision making across the DRR cycle through co-design, co-development and co-evaluation of service development based on a more comprehensive understanding of the risks to associated decisions.

3.2 Hydrogeological

According to EUCPM Participating States assessments, floods and landslides are the most frequent and impactful natural hazards faced by the European management authorities, and intensities have been changing through climate change.

Floods comprised different kinds of events including coastal, river and surface floods, pluvial floods, flash floods etc. They occur in very diverse geographical contexts whose features influence the evolution of the phenomenon itself. Heavy rainfall, thunderstorms, rapid snow-melt and dam failures are the most frequent trigger of flooding events.

Landslides are not included in the Overview, even though the hazard is rather widespread over the entire European territory. The potential for landslides increases due to erosion processes, permafrost degradation, water saturated soils after rainfall and snowmelts, rain events following forest fires, deforestation and soil sealing from construction activities.

The likelihood of exposed elements being affected by such hazards depends on geographical or environmental conditions (soil types, water retention capacity of soils and vegetation), land use, urban planning and the nature and design of the built environment.

Major flood events may have significant importance in densely populated areas prone to multiple flood types. The impact of these events can affect people, local economy, infrastructures and services, environmental and cultural heritage.

Ten NRAs consider flooding as a high-level risk, while eleven of them recognize the link between flooding and climate change. A recurring cascading effect identified is the interruption of critical infrastructure/ transportation, dike failures, landslides and (as in the case of Malta) direct consequences for tourism and fishing. It is widely acknowledged that climate change and extreme water-related events can enhance the frequency and extent of floods and landslides. Denmark, Norway, Romania, Hungary, UK and Italy recognise climate change and extreme weather events as aggravators of flood and landslide risk.

Cross border risk due to major floods is addressed by NRAs considering river basins that span different countries. According to UCPM activations between 2006 and 2016, flood events affected mostly south-eastern Europe, especially countries within the Danube river basin, south-eastern France, central and southern Germany (Rhine basin) and UK.

A number of EU research projects on hydrogeological and geological risks have been undertaken, dealing with methodologies of risk analysis, management and governance (e.g. FLOODsite [51], IMPRINTS [52], STARFLOOD [53], HAREN [54]), floods and resilience in urban areas (CORFU [55], ACHELOUS [56]), prevention measures (FLOOD CBA [57]) and risk partnerships (ENHANCE [58]).

The EU Flood Directive [59] launched in 2007 has envisaged the need to produce reliable flood risk assessments for each river basin district within the national territories of Europe, and the European Flood Awareness System (EFAS [60]), part of the Copernicus emergency management services, is a system for monitoring and forecasting floods across Europe.

51 http://www.floodsite.net/
52 http://www.crahi.upc.edu/imprints/
53 http://www.starflood.eu/
54 http://aqua.upc.es/haren/
55 http://www.corfu7.eu/
56 http://www.achelous.eu/
57 http://www.floodcba2.eu/site/
58 http://enhanceproject.eu/
59 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32007L0060
60 www.efas.eu

Main research gaps and needs

- Improved understanding of relations linking climate change and hydrological hydrogeological events.
- Improvement of monitoring networks and early warning systems in flooding (especially flash-floods) and landslide risk-prone areas.
- Improvement of the ability to predict pluvial flooding events, the understanding of their impacts and means of mitigating the consequences.
- Improvement of loss and damage monitoring in collaboration with the private sector (insurance) and implementation of EU-shared databases, hubs or platforms.
- Increased efforts for the operation of regional scale landslide forecasting and early warning systems.
- Exploiting the added value of nature-based solutions for DRR in relation to the different types of hazard.
- Further exploration of probabilistic forecasting methods and impact focused scenario building including clear communication of uncertainties.
- Utilisation of parallelisation of modelling approaches and high-performance computing.
- Integration of weather forecasts and quantitative rainfall forecasts and live measurements of precipitation.
- Further exploration of satellite information, in particular from the Sentinel constellation.

3.3 Forest fires

Forest fires across Europe are a recurrent hazard, with the most affected areas being in Southern Europe and the Mediterranean region, while there exists a low likelihood in the Scandinavian peninsula and the Baltic region. As examples of how serious this hazard can be, forest fires in Greece in 2007 and in Portugal 2017 claimed 80 and more than 100 lives, respectively. In 2018, 99 lives were lost in Greece, 2,500 people were evacuated in Portugal and Spain, 50 people evacuated in UK, while Sweden had to face the most serious series of forest fires in its modern history, although with no fatalities.

Forest fires are a natural cleaning process of forests, and the suppression of forest fires can lead to the production of excessive biomass, eventually leading to even more catastrophic events. The majority of forest fires are caused by human actions, which is difficult to predict in any form. These events can be very localized, and their likelihood and impact depend on climate and weather conditions (winds, temperature, precipitation, etc.), topography, vegetation type and the accumulation of dead biomass, and the local fire brigade's preparedness and response capacities.

Six of the NRAs identify forest fires as high impact hazard and as linked to climate change. The increase in temperatures in central and northern Europe is likely to cause more forest fires in the Baltic and Scandinavian regions. The loss of biodiversity (destruction of flora and fauna) may be a critical result of these events (e.g., deforestation in Poland) and the subsequent degradation of areas with high naturalist value can have a significant economic and non-economic impact on human health, wellbeing and culture. At the same time, the presence of specific plant species (e.g. reforestation with eucalyptus plantation in Portugal) are relevant aggravation factors. Damage to properties and critical infrastructure can cause very high economic losses, especially in areas with large natural-built interfaces, where the phenomenon is going to increase in likelihood and impact. Further impacts, often not considered but highly relevant, concern water quality post-fire, a potentially costly issue with still many knowledge gaps.

Cross-border issues associated with forest fires are recognized along frontiers between Finland and Russia, while cascading effects, such as the interruption of transport and energy infrastructure, is little recognized due to the localized impact of fires.

At the EU level, measures and actions to prevent or prepare against forest fire and reduce the associated risks are in place. The protection of forests in Europe is included in EU Forest Strategy [61] approved at the end of 2013, the EFFIS [62] early warning system (part of the Copernicus Emergency Management services) is a support tool for the protection of forests against forest fires, while the European Fund for Rural Development (EAFDR, 2007) supports natural restoration and prevention before and after forest fires.

61 https://www.eea.europa.eu/policy-documents/the-eu-forest-strategy-com
62 http://effis.jrc.ec.europa.eu

A number of European research projects have focused on the linkage between climate change and forest fires (PESETA II [63], FUME [64]) and on preventive measures for the sustainable management of forests (FIRESMART [65]). As for national practices, Italy has developed a tool for fire risk mapping, as well as developing fire danger forecast and propagation models to be used for the prevention and response phases. The PLACARD [66] project has developed a policy brief with concrete research recommendation.

Main research gaps and needs

- Improvement of transboundary collaboration and response resources sharing in consideration of the climate change trends.
- Improvement of risk assessments methods that reflect the effects of climate change (droughts, heat waves, etc.).
- Improvement of monitoring of loss and damage (direct and indirect) due to forest fires and the compilation of information in databases in a consistent way, ensuring long-term perspective of hosting and maintaining.
- Extended fire monitoring, forecasting and early warning, including the improved integration of weather data in fire forecasting.
- Improvements in understanding of associated prevention and recovery strategies (e.g., forest management, land-use and land cover changes including human encroachment) in the context of climate change, as well as how these would impact on preparedness and response strategies and plans.

3.4 Earthquakes

Most earthquakes around the World are generated along the boundaries of tectonic plates. The Eurasian plate is bounded to the west by the Mid-Atlantic Ridge that runs across Iceland and nearby the Azores. The southern boundary runs along northern Africa, and continues to the east across southern Italy, Greece, Turkey, and Cyprus. Here there are also three subduction zones which are known to generate the largest earthquakes. Another very active plate boundary is represented by the North Anatolian Fault, in northern Turkey.

Intracontinental earthquakes also pose significant risks because the population is often not prepared and in Europe one of the most active intracontinental zones is Vrancea, Romania.

Intensity and frequency of earthquakes cannot be predicted with accuracy, nevertheless high-quality long term, probabilistic seismic hazard models are available for individual Member States and for the entire continent. Other tools for modelling the expected damage to exposed elements (buildings, critical infrastructure, public services, human lives), including early warning systems and economic impacts assessment tools, can better inform earthquake risk management. Major earthquakes over the last decades in Italy (2002, 2009, 2012, 2016, 2017), Greece (2014, 2016), Iceland (2014) and Spain (2011) have caused the loss of around a thousand lives and inflicted economic losses across Europe. Italy is characterized by a particularly high level of seismic risk and is the most affected nation in Europe. Thus, starting from 2003, a seismic classification of the whole national territory was implemented, together with dedicated legislation dealing with mitigation and prevention.

The impact of earthquakes is naturally dependent upon the location and magnitude of the event: occurrence in densely urbanized areas can have a severe impact depending on land use and on the vulnerability of buildings, especially where most of the existing building stock was built before the enforcement of the EUROCODE and local building codes to provide technical guidance for aseismic building construction.

In the Overview, five nations in their NRAs recognized earthquakes as having a low likelihood, but high impact or catastrophic impact, considering the worst-case scenario (expected magnitude earthquake based on past event). Active zones of seismicity that cross national borders may see such events having a transboundary impact, especially in the Balkan and Alpine regions.

Earthquakes are also potentially responsible for a range of cascading effects (landslides, rockfalls, avalanches, tsunamis, interruption of critical infrastructures, etc.). The Overview shows that five nations have indicated related cascading effects such as landslide, flooding, infrastructure damage and tsunami.
EU research projects on seismic risk have

63 https://ec.europa.eu/jrc/en/peseta
64 http://fumeproject.uclm.es/
65 https://cordis.europa.eu/project/rcn/93946_en.html
66 https://www.placard-network.eu/impacts-of-fires-on-water-quality

focused on seismic hazard assessment, vulnerability, and risk analysis for buildings and critical infrastructures (e.g., Syner-G[67], STREST[68], SHARE[69], NERA[70]) and on real time risk reduction (REAKT[71]). The DACEA[72] project for cross-border earthquake system between Bulgaria and Romania has improved response capacity and has developed a near-real time damage assessment to help rescue and recovery operations in both countries. The SERA[73] project integrates data, products, infrastructures and know-how in seismology and earthquake engineering to build a research infrastructure alliance in EU.

Main research gaps and needs

- Improved monitoring of earthquake activity throughout the European region.
- Improvement of seismic source data collection across EU (e.g., seismogenic faults and subduction zones) and estimates of their seismic potential and efficiency.
- Seismic/aseismic behaviour of tectonic zones and earthquake magnitude frequency distribution across different time frames.
- Characterization of the expected ground motion.
- Improvement of exposure data collection across EU.
- Standardization of procedures at EU level for post-event assessments and technical management of emergency (e.g., safety surveys on damaged buildings).
- Improved understanding of the fragility of different components of the built environment, especially infrastructure and buildings built prior to existing codes of practice.
- Development and testing of improved strengthening methods for existing buildings and infrastructure.
- Improvement of capacity of critical infrastructure systems to automatically respond to early warning alerts.
- Investigation of consequences of likely cascading effects from earthquakes.
- Embedding of resilience measures and predictive analytics techniques.
- Exploration of big data and crowd sourcing information for seismic monitoring.

3.5 Volcanic eruptions

Volcanic risk is not present in the Overview, even though it exists in Europe within a diverse range of contexts. Active volcanoes around continental and non-continental Europe are a serious threat for European citizens, as major volcanic explosive eruptions can be very destructive. Luckily, in Europe the occurrence of this natural phenomenon remains quite rare. The highest volcanic activity is localized along the Eurasian plate boundaries, in southern Europe (Italy and Greece), the Canary Islands, Iceland, Norwegian islands and in overseas territories. Known volcanic areas are also located in western Germany, central France, and in continental Spain. The most dangerous active volcanic area, in terms of potential impact on the local population and built environment, is the Campania region in southern Italy. Of the 15 million people in Europe living within 30 km of an active volcano, more than 2.2 million live within 20 km of the Campi Flegrei caldera in Italy and more than 800,000 live within 10 km of Vesuvius. These volcanoes are characterized by explosive activity and are located in one of the most densely populated areas of Italy, and for this reason are among the most dangerous, and at the same time most monitored and studied, volcanoes worldwide.

The effects of a volcanic eruption include ash-fall, lava flows, emission of toxic gases, lahars and volcanic earthquakes. The geographical extent of ash falls depends on the volumes being ejected and wind direction, while lahars are connected to the presence of slopes which can cause the sliding of unstable deposits. There is also the connection between volcanic activity, earthquakes and tsunamis, as for the case of Iceland or active volcanoes in the Aeolian Islands.
EU research and innovation project on volcanic

67 http://www.vce.at/SYNER-G/index.htm
68 http://www.strest-eu.org/opencms/opencms/
69 http://www.share-eu.org/
70 https://cordis.europa.eu/project/rcn/96282_en.html
71 http://www.reaktproject.eu/
72 http://www.adodunav.org/en/page/dacea
73 http://www.sera-eu.org/

risk have focused on volcanic risk assessment, long term monitoring and forecasting (e.g., EXPLORIS [74], FUTUREVOLC [75], VUELCO [76], MIAVITA [77], DORIS, etc.) and infrastructures for volcanic risk management (e.g. MED-SUV [78], etc.).

Main research gaps and needs

- Further studies to improve the forecasting ("predictive analytics") of intensity and expected time of eruption following unrest conditions.
- Improve understanding of the fragility of the built environment and economic activities to each of the principal volcanic hazards (tephra fall, pyroclastic flow, lahars) separately and in combination.
- Improvement of impact studies, focused on cumulative damage due to the potential sequences of volcanic phenomena, and on the long-distance impacts on critical infrastructures and service networks.
- Improvement in understanding responses and recovery associated with volcanic events, including consideration of cascading impacts as a result of dependencies and interdependencies from a systems perspective.
- Development of standardised approaches to post-event damage and impact assessments.
- Improved studies and exercises to test the effectiveness of emergency management processes.

3.6 Tsunamis

The Mediterranean area is characterised by both subduction and collision of plates boundaries running under the open sea or in the near offshore. Earthquake generated along these boundaries are the major cause of the largest tsunamis. Tsunamis can also be generated by submarine earthquakes, submarine volcanic activity, underwater sediment slumps and slides.

There are differences with regards to the triggering mechanisms observed in different areas of Europe, because of the existing geological differences. Volcanic activity is a frequent tsunami-triggering process, especially in Canary and Azores islands, Italy and Greece. In the context of volcanic islands, many slopes are potentially unstable and can produce mass movements or may collapse into the sea during a major explosive volcanic eruption causing a tsunami.

The largest known earthquake-generated tsunami is also the oldest for which there is historical evidence. This is the case of the 365 CE of Crete, which spread destruction across the eastern Mediterranean. Other deadly earthquakes and tsunamis date back to 1693 in eastern Sicily and in 1755 in Portugal. In addition, a very strong earthquake and tsunami took place in the Strait of Messina in 1908, causing severe damage and many victims. In the Black Sea, researchers have documented nine tsunamis in the 20th Century, including one after Turkey's 1999 Izmit earthquake. The most recent earthquake-generated tsunamis are the 2003 Boumerdes, Algeria, and 2017 Bodrum-Kos on the Greece-Turkey boundary.

After the tsunami of December 2004 in the Indian Ocean, the international community moved to create new regional tsunami warning systems. Since that date, the International Oceanographic Commission of UNESCO has received the mandate to coordinate the implementation of a tsunami alert system (NEAMTWS [79]) in the NEAM region (North-Eastern Atlantic, the Mediterranean and connected Seas) which play a crucial role due to the presence on the coastline of an ever-increasing population and great number of critical infrastructures.

Tsunamis are also included in the ARISTOTLE project and a probabilistic tsunami hazard model for seismically induced tsunamis has been developed within the TSUMAPS-NEAM [80] project for the NEAM region, ended in the late 2017.

Main research gaps and needs

- Further studies and implementation of early warning systems, including submersion levels estimation based on High Performance Computer modelling.
- Detailed inundation modelling of various potential scenarios and better integration into emergency plans.
- Improved evacuation planning and communication, including self-evacuation education.
- Extended and refined mapping of offshore

74 http://exploris.pi.ingv.it/
75 http://futurevolc.hi.is/
76 http://www.vuelco.net/
77 http://miavita.brgm.fr/
78 http://med-suv.eu/
79 http://neamtic.ioc-unesco.org/
80 www.tsumaps-neam.eu

faults and subduction zones and estimates of their seismic potential.

- Improved understanding of the peculiar physical conditions that trigger the tsunami following seismic events.

- Development of probabilistic framework to assess tsunami hazard generated by landslides and volcanic activity.

3.7 Na-Tech events

Natural hazards can result in significant impacts on industrial facilities and critical infrastructure disruption, thus triggering so-called "Na-Tech" (Natural – Technological) risks. These can produce toxic substances spills, fires, explosions and the disruption of critical services (transport, power, water supply, communication) in highly populated and industrialized areas, resulting in cascading effects with severe impacts on communities and the economy. The disaster of Seveso, Italy, in 1976 is known to have caused the highest exposure of a residential population to dioxin in the world. This event gave rise to international attention and led to the industrial safety regulations known as the EU Seveso II Directive [81], which obliges EU Member States to have prevention and response policies for industry operators.

One of the most serious Na-Tech incidents in recent years was the nuclear accident at the Fukushima Nuclear plant in Japan in 2011 resulting from the impact of the tsunami generated from the northern Japan earthquake. It is important to realise that while the plant was designed according specific seismic regulations, the risk posed by tsunami was inadequately addressed. The Fukushima event indeed focused attention on the necessity to develop multi-hazard assessments for major industrial facilities as well as the need to consider uncertainty in hazard modelling (especially for critical facilities) and a system of back-ups.

The main focus on Na-Tech risks indeed lies on a thorough understanding of the vulnerability of industrial sites and critical infrastructure with respect to the potential natural hazards. This entails the identification of both physical (safety of building facilities and structures) and operational (back-up time, redundancies of the systems, etc.) vulnerability, often addressing multi-hazard conditions. Multiple fields of expertise need to be involved to ensure reliable risk assessments are made which identify suitable mitigation and resilience measures.

Main research gaps and needs

- Further studies focusing on the probability of transition between hazards in cascading events

- Advanced modelling methods such as sector models, system dynamics approaches and data farming techniques and application experiments, especially focused in critical infrastructures and their interdependence.

- Integrated Reachback Information Systems (IRIS).

- Comprehensive risk modelling including worst-case scenarios, taking into account cascading effects.

- Improvement in our understanding and capabilities to identify and mitigate risks associated with interdependencies across infrastructure and other human (social and economic) systems.

81 http://ec.europa.eu/environment/seveso/index.htm

4 Future research vision

4.1 Natural hazards research and innovation topics

Dealing with DRR and CCA in a resilience-oriented perspective entails strengthening interdisciplinary collaboration across diverse disciplines and research areas, to identify answers and solutions adequate to the systemic complexity of the challenge.

This approach assumes that urban, suburban, rural and natural environments are complex systems resulting from the interaction of different subsystems: the physical system, the relational and functional system and the socio-economic system. Disaster risk and climate change are producing increasing crises and deep changes in each of these subsystems, with consequences for future directions of society as a whole. Seeking appropriate solutions must therefore recognise and reflect on the complexity and systemic nature of DRR and CCA when identifying and implementing solutions.

The challenge here is to bridge scientific research, technological innovation, national and transnational policies, operational practices, cultural preservation, local identity and relationships. This can be done by using a multidisciplinary systematic approach where architectural and urban disciplines, systems engineering, social science, earth sciences, IT and data visualization, probabilistic modelling and scenario analysis, are called to focus on identifying and communicating effective and adaptive solutions to the challenge of ensuring sustainable growth in a globally connected world, while dealing with increasingly complex disaster risk conditions aggravated by a climate change perspective.

At European level, such an approach needs to be achieved by streamlining research and innovation pathways that take advantage of the best available practices implemented by the single Member States, often related to specific local priorities in terms of hazard occurrence. This would imply the fostering of geographical and/or thematic DRR and CCA "alliances" based on common hazards/risks and by orienting future research activities according to specificities and common tasks across European regions and nations, as well as neighbouring countries.

Geographical-based alliances could for example, involve countries in seismic-prone regions in developing advanced earthquake monitoring and modelling techniques, as well as sharing best practice for emergency planning, management and to Build Back Better in recovery.

Thematic alliances could enable knowledge-sharing processes among countries and support the ability to cope with emerging hazards such as those induced by climate change. The recent impact of heat waves, drought and forest fires in north European regions could be mitigated by enhancing the collaboration with south European countries in key fields such as urban design and emergency response capacity.

The reinforcement of regional and international networks and forums on DRR/DRM (also as part of the EUCPM) could strongly influence on policies and transboundary agreements.

In this sense, some commonly raised questions are the following:

- How can we forecast, anticipate, and prevent risks from disasters caused by natural events?
- How can we discretize, collect and use all the existing information and data on natural hazards?
- Do disasters caused by natural events spur advances and how can we best capture technological innovations that can reduce the risk of future hazards?
- Can we better understand human behaviour before, during and after a catastrophic event, and how can we use such understanding to inform DRR?
- Does the degree of influence of risk perception vary across different countries and cultures?

4.2 The Horizon Europe Framework Programme

With a total budget of €97.6 billion, Horizon Europe, to be launched on January 1st 2021, will be the largest ever research and innovation EU funding programme. The framework will be designed around three pillars: "Open Science", "Global Challenges and Industrial Competitiveness" and "Open Innovation".

In particular, the Global Challenges and Industrial Competitiveness pillar is expected to combine the Horizon 2020's 'societal challenges' and 'leadership in enabling industrial technologies' into one consolidated focus. The seven existing societal challenges in Horizon 2020 are expected to be rationalised into broad topics to "support EU policy priorities in areas such as

the achievement of the SDGs, health, food and natural resources, resilience and security, climate, energy and mobility to secure a low-carbon, circular and climate-resilient society, industrial competitiveness and other societal challenges".

This pillar intends to be "built on clusters that aim at exploiting European strengths and assets by generating new knowledge and translating it into useful innovations, developing and applying digital and key enabling technologies along with a new mission approach", and retaining "industrial leadership" as a prominent element "within the pillar and through the programme as whole" (EC, SWD (2018) 171 final).

The mission-oriented approach to policy-making sets defined goals, with specific targets and roadmaps for implementation, with the aim of maximising the impact of this and future EU Framework Programme for Research and Innovation. This approach is intended to maximize impact by setting clearer targets and expected impacts when addressing global challenges, thereby making it easier for citizens to understand the value of investments.

The Mazzucato Report[82] highlights the potential of such a problem-solving approach to fuel innovation-led growth, as it will "provide a massive opportunity to increase the impact of European research and innovation, grasp the public imagination and make real progress on complex challenges" (Mazzucato, 2018).

The recent call for feedback[83] on the Report have highlighted the main characteristics of the Research and Innovation missions to be designed, indicating that they should:

- have ambitious but realistic Research and Innovation actions;
- be bold and inspirational with wide societal relevance;
- have a clear direction, be targeted, measureable and time-bound;
- foster multiple, bottom-up solutions; and
- be cross-disciplinary, cross-sectoral and cross-actor.

In terms of implementation, EU Research and Innovation (R&I) missions should:

- be flexible, with pro-active management and building in-house capabilities;
- have a clear goal and milestones to measure impact;
- engage a diverse set of national and regional stakeholders; and
- be implemented through a portfolio of instruments to foster bottom up solutions.

Future research missions that contain these aspects can contribute to shape a coherent vision on how to structure the key missions and actions related to the natural hazards' domain in the Horizon Europe Programme, following the relevant gaps and needs as expressed by the network of stakeholders engaged within ESPREssO activities.

The natural hazard community needs to strengthen the cooperation to address challenges of common interest in a specified area of Research & Innovation and supporting the European Commission on programming relevant scientific investigations[84].

The following sections include five broad Research and Innovation area proposed by the ESPREssO team and network, structured as suggested calls for proposals by identifying for each of them the scope, objectives and expected impacts:

1. Improved risk and impact assessments
2. Better data for a resilient future
3. Risk governance and partnerships
4. Overcoming the implementation gap in DRR and CCA
5. Human behaviour and disaster risk

4.3 MISSION 1. Improved risk and impact assessments

Specific mission

Simulation-based risk and impact assessments represent an effective approach to make science understandable to decision makers and streamline national to local mitigation/adaptation actions. This is especially the case if they are integrated with tools for cost-benefit and multi-criteria analyses, data-farming experiments, and are tailored according end-users' needs, to assess the effectiveness of alternative options in the different phases of the DRM cycle. Such an approach

82 https://ec.europa.eu/info/sites/info/files/mazzucato_report_2018.pdf
83 https://ec.europa.eu/info/sites/info/files/mazzucato_report_missions_feedback.pdf
84 https://www.scienceeurope.org/policy/policy-areas/framework-programmes/

implies that specific assessments must be decision or demand driven (and science-informed) and that there is a clear need to translate the results (thus for translational science) so as they are relevant, usable, legitimate and credible from the perspective of the users. Co-design, co-development, co-dissemination and co-evaluation engaging the intended end users represent in this sense key features of improved risk and impact assessments.

In the "prevention" phase, the understanding and quantification of physical and economic impacts due to natural or Na-Tech hazards can effectively orient resilient land-use planning and retrofitting of buildings, transport networks and critical infrastructures, as well as improve the risk coping capacity by ensuring an effective emergency planning, providing the allocation of response resources in the territory according to the expected risk/impacts.
In the "preparedness" and "response" phases, especially in the case of forecastable events, the improvement of probabilistic impact simulation models, able to produce actionable results in real or near-real-time can support the implementation of operational plans, providing support to decision-makers in relation to specific short-term preparedness actions, such as evacuations, provisional shelters and/or protection measures to households in the affected area.

In the "recovery" phase, post-event damage assessments and the evaluation of damage mechanisms of relevant elements at risk can improve the understanding of possible ways to Build Back Better and to recovery the local daily life, including local economy, identity and culture. Effective and systemic assessment of recovery options and their implementation is therefore needed.

To support the great potential of a strategic perspective related to knowledge and evidence-based policy and decision-making, the scientific community is called upon for a coordinated effort aimed at producing innovative methods and tools for reliable risk and impact simulations, including the assessment of alternative resilience and recovery options.

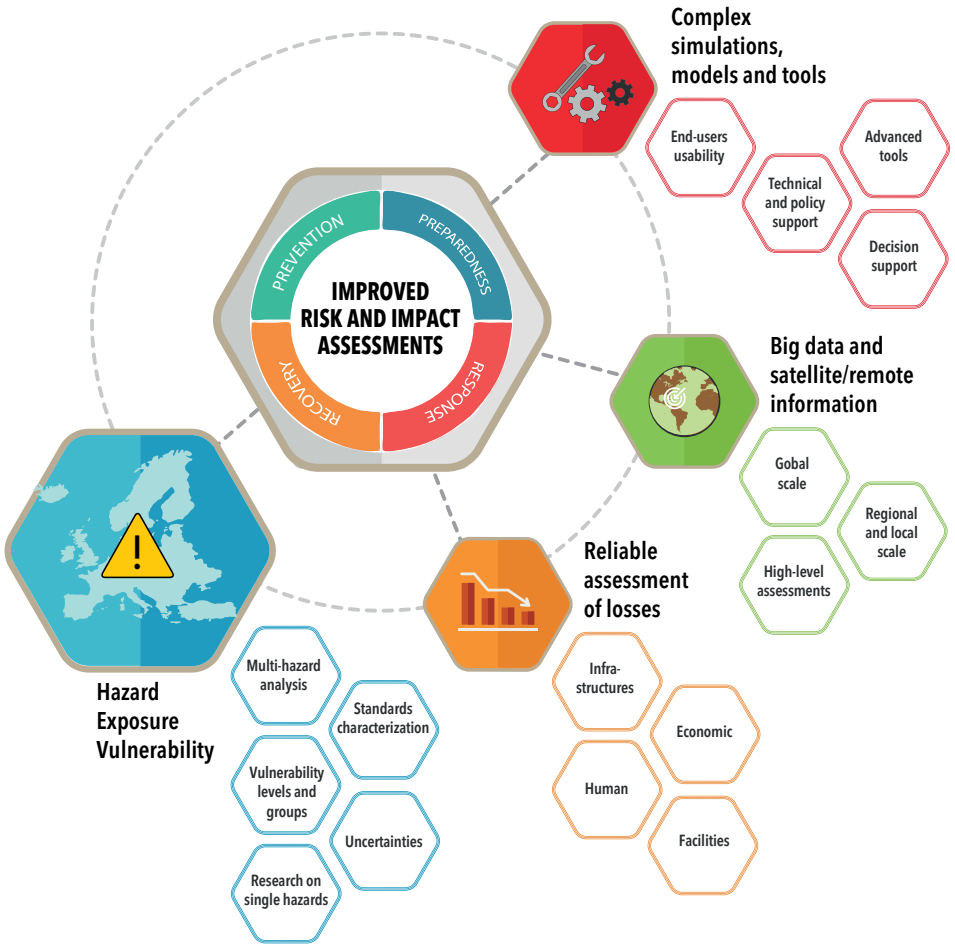

Figure 10: *MISSION 1. Improved risk and impact assessments*

Action

The specific action proposed to improve risk and impact assessments is to acquire more useful, usable and evidence-based knowledge to inform resilient design and emergency planning and management measures, tackling the full DRM cycle. An interdisciplinary effort is required to take advantage of the most advanced science-based hazard/impact assessment methods, to streamline their contribution to the needed evolution of policy and legislation. Multi-risk assessments and all-hazards approaches (including Na-Tech and cascading effects) need to be strengthened, overcoming the limitation of single-hazards assessments in defining suitable and cost-effective resilience measures in regions potentially affected by multiple sources of natural hazards.

Three priorities are identified within the scope of such action:

- foster service-oriented thinking, aimed at maximising the usability and the end-user-tailoring of complex simulation and optimization models and tools developed by the scientific community with the engagement of the intended users, both to support technical policy improvements and for the implementation of specific actions;

- promote the exploitation of big data and satellite/remote sensing information, to improve high-level assessment and identify priorities (within reachback processes) at international and regional scales;

- achieve a reliable quantitative assessment of both losses and benefits of resilience recovery measures (physical, functional and economic), understanding their propagation among different geographical areas, infrastructure networks and economic sectors.

Hazard, exposure, and vulnerability are taken to be the key "elementary bricks" of risk and impact assessment, therefore are also essential components for identifying actions to build resilience and implement adaptation. Hence, specific advancements are needed in relation to each of them:

- Hazard
  - improve basic research on hazards and understanding of hazard dynamics based on new methods arising from technological innovation in the field of monitoring and forecasting, investigating the underlying processes of hazardous events, especially in the field of climate change-related hazards including heat-waves and forest fires and low-probability/high-impact events such as Na-Tech and/or explosive volcanic eruption;
  - in the case of low-probability/long time recurrence events (with the exclusion of hazards induced or aggravated by climate change), investigate in depth past events in order to assess where, when and with which intensity future events may occur. This includes for example a higher completeness of the historical-geological records of volcanic eruptions, major earthquakes, tsunamis, etc.
  - standardize hazard characterization methods for single-hazards, multi-hazard, cascading effects and Na-Tech;
  - identify the major sources of uncertainty in hazard assessment and promote research to reduce them;
  - harmonize spatial and temporal scales of reporting different hazards (e.g. region-wide vs. site-specific; short-term vs. long-term);
- Exposure and Vulnerability
  - develop innovative exposure and vulnerability analysis methods, including those that take a systemic perspective by integrating sectorial expertise, specific knowledge domains (e.g. social science, human health, cultural heritage, environment and biodiversity, key economic sectors as tourism and industrial/agricultural production, etc.) and recognising differentiated vulnerabilities, including those most vulnerable groups, also in the light of a changing climate;
  - develop methods for a reliable estimation of the indirect economic losses and societal impacts;
  - standardize exposure and vulnerability analysis methods for single-hazards, multi-hazard, cascading effects and Na-Tech;
  - improve multi-hazard risk analysis.

Innovative assessment methodologies need to provide decision-makers and end-users with actionable information able to overcome the main gaps and needs emerging from the current state-of-the-art in this field, and consider, including from a systemic perspective:

- the implication of cumulative damage from cascading effects and Na-Tech;
- the evaluation of dynamic variables related to space, time and human behaviour;
- the effect of maintenance and retrofitting operations on exposed assets;
- the evaluation of uncertainties and error propagation in probabilistic approaches and models;
- the development of indicators and metrics for multi-sectorial resilience assessments strictly connected in terms of input/output to the risk/ impact assessment/simulation models;
- the addition of quantitative data, parameters and uncertainties on social vulnerability that can be integrated in the risk analysis.

Expected impact
The expected impact of the action includes:

- increasingly standardized risk and impact modelling methodologies and procedures (including the modelling of resilience adaptation measures and their integration into the modelling workflows) exploiting the potential derived from the integration of methods and tools developed by a variety of actors in the EU (governments, research centres, industry, SMEs, etc.);
- improved understanding and modelling of operational and organizational processes (including human behavioural aspects) to properly model functional and economic losses as a priority in assessing social and systemic vulnerability, while also considering the cascading failure of service networks and critical infrastructures;
- reliable methods for time-dependent and multi-hazard vulnerability analyses of systems and their elements, to produce risk/impact assessments based on quantitative indicators (including the effect of resilience adaptation measures).
- advanced decision-support tools based on integrated all-hazards approaches and what-if scenarios to identify trade-offs, co-benefits of integrated mitigation and adaptation measures, common resilience pathways and management approaches (integration of smart management cockpits).

4.4 MISSION 2. Better data for a resilient future

Specific mission
Research in the field of natural hazards is increasingly dependent on the quality and availability of data, needed to characterize hazard, exposure and vulnerability conditions in different geographical areas and sector-specific (i.e. critical infrastructure) contexts, as well as to assess and evaluate the performance of measures introduced to reduce vulnerabilities and enhance resilience.

Data are, in this sense, an essential component of any reliable model or tool that aims to provide better knowledge and decision support in DRM, DRR and CCA. However, an overwhelming amount of information, that while available is scattered among multiple sources, hampers the development and implementation of required actions by decision makers to increase resilience and identify actionable strategies involving the entire emergency cycle.

In this sense, the effort produced at the EU level with the Copernicus initiative is oriented towards a progressive harmonisation of core datasets, by combining satellite acquired data and information with in situ data across Europe.

National and sub-national public datasets and geo-portals also represent an essential source of detailed information, often needed when, e.g., performing vulnerability analyses and risk/ impact assessments.

Together with datasets specifically built from earth observation or census data, the ever-growing presence of "Big Data" in various fields, accelerated by fast ICT developments linked to machine learning and social media data mining techniques for example, poses the issue of how to transform such content into relevant, usable, legitimate and credible data and information for further analyses and exploitation, as well as dealing with the significant issues in terms of privacy and ownership.

Furthermore, the full operationalization of DRR/DRM key tools, such as early warning systems and real-time or near-real-time

simulations and alert systems, still sees a weak point in the accessibility of privately-owned sensitive data, such as that related to critical infrastructures' safety and operation.

Emerging issues are related to data sharing and management between researchers, institutions and stakeholders, as well as to structured and coordinated data collection processes to overcome the observed lack of data and to meet the needs for updating.

In the "preparedness" and "response" phases, more structured and widely available datasets can support both long-term strategic planning, feeding hazard/impact simulation models with the needed level of detail, and short-term emergency management strategies (such as data to support tactical operational issues during these phases, e.g. deployment of resources), through their connection with early warning and alert systems.

In the "recovery" phase, harmonised techniques for post-event data collection, such as technical surveys to determine damage level, financial reporting and technical monitoring of reconstruction activities (e.g. the USRA initiative following L'Aquila earthquake, www.usra.it).

To support the needed advancements in the field of data collection, harmonisation and exploitation, the scientific community is called upon for a coordinated effort aimed at producing innovative methods and tools for advanced data collection and analytics methods, including specific procedures for data management within hazard/impact simulation models, decision support, early warning and alert systems.

Figure 11: *MISSION 2. Better data for a resilient future*

Action
The specific action proposed aims at fostering the diffusion of high-quality and structured datasets to support the implementation of improved services to support DRM, DRR and CCA.

Public-private cooperation is identified as a crucial aspect to streamline the use of already existing data. The proposal should include innovative exploitation models to define possible compensation strategies to allow EU and national institutions to acquire within the EU open source datasets (e.g. the Copernicus Services) and privately-owned datasets. Advanced data-mining techniques such as data-farming should be explored and further developed to streamline an effective use of big data, providing innovative methods to improve their integration within models and tools.

The relevant datasets that should be considered include:

- Hazard
  - improve the real-time availability of data from monitoring networks within a reachback architecture;
  - expand and improve the databases of the hazard sources (location, potential, magnitude-frequency distribution);
  - create a harmonized database of hazard data from past events (location, magnitude, intensity);
  - improve the availability of detailed climate information (up to the urban neighbourhood scale) using dynamical downscaling and statistical methods to propagate uncertainties across spatial and timescales.
- Exposure
  - better detail in the knowledge of the characteristics of the elements at risk in relation to different hazard sources, building a GIS-based exposure data repository at the EU-level through the exploitation of national and sub-national datasets, with particular reference to population (demographics, gender/age distribution, economics); built environment (land use and Functional Urban Areas, building heights, recurring construction techniques, features of open and green spaces); critical infrastructure, transport and service networks.
- Vulnerability
  - develop hazard-specific vulnerability classes for the EU based on detailed exposure datasets;
  - systematize and harmonize vulnerability functions for each hazard and relevant elements at risk to produce a EU level repository in support of risk assessments and impact simulations;
  - develop datasets related to resilience and adaptation measures, assessing their efficacy and performance in relation to vulnerabilities. This include improving availability of data on actions being taken and providing information to support learning and sharing of experiences and challenges.
- Impact
  - contribute to the consolidation of the JRC initiative for the creation of a Loss Database for DRM and foresee specific areas for detailed country information.

Expected impact
The expected impact of the action includes:

- understanding the effects of using improved common protocols and procedures for data collection and analysis;
- possibility of a continuous update of data and their dissemination to decision makers, the general public and communities;
- contribution to the improvement of Copernicus Services through new pan-European datasets, bridging existing datasets at the national level (e.g., building heights construction typologies, transport and service networks, etc.);
- inclusion of Public-Private Partnerships (PPPs) to streamline data collection and exploitation within early warning systems;
- web services for the use of big data within real and near-real-time simulation tools embedded in a DRM cycle and holistic reachback processes;
- creation of networks of cloud- and web based services allowing based on data sharing and custom-fit applications.

4.5 MISSION 3. Risk governance and partnership

Specific mission

In complex contemporary societies, the capacity of communities and governments to manage expected and/or unexpected events depends heavily on effective governance throughout the entire DRM cycle. This extends from prevention to recovery, enabling effective operational mechanisms and resources mobilization to reduce the impact of natural hazards. However, in recent decades, new issues interlinked with DRR have arisen. These include climate change, water scarcity, poverty growth, and environmental pollution, which have highlighted the need for a more comprehensive risk governance approach, shifting from the mere short-term DRM to long-term resilience strategies.

At the global and EU levels, a coherent integration between DRR and CCA policies and SDGs as fostered by UN major initiatives (Sendai Framework; Paris Agreement; New Urban Agenda) should result in a comprehensive resilience framework, while also improving synergies and coherence among the institutions and international agencies involved. The effective implementation of global and European polices at regional, national and local levels, for effective disaster risk governance in all phases, requires collaboration and information sharing across all involved institutions including the private sector. Cross-regional, transboundary and cross-sector agreements covering all phases of DRM can improve the knowledge on common hazard/risks and improve effective response and recovery

Figure 12: *MISSION 3. Risk Governance and Partnership*

based on specific national or local expertise and experience (e.g. training exercise and best practice sharing). At the national/regional level, it is important to overcome silos between technical and political authorities and advocate integration among the actors involved. In this sense, disaster risk partnerships (e.g. Natural Hazards Partnership[85] in UK) can enhance collaboration between public and private bodies, providing effective and useful hazard/impact and risk assessment information to communities and governments for prevention, mitigation, adaptation and response.

Multi-risk governance frameworks, shifting from single to multi-risk thinking in governmental agencies, represents the key challenge for the future, considering how measures to improve the resilience of the built environment and communities are often able to provide effective solutions to conditions involving multiple natural hazards. A strong leverage on political commitment and the improvement of capacity and capabilities to overcome the implementation gap is needed in order to increase the awareness of local authorities. The engagement of local communities in DRM for prevention, preparedness, response and recovery in support of Civil Protection operators leads to a responsibility sharing mechanism among the stakeholders involved at all levels.

Action

Specific actions are proposed in order to improve disaster risk governance throughout the entire DRM cycle at the national and transnational levels. To boost the leverage of political commitment and funding of DRR initiatives and policies, strong public participation and active collaboration among sub-national, national and transnational bodies (both public and private) is needed. This implies creating and supporting an effective partnership across government levels, and with the private sector, civil society, communities and individuals all of which need to accept their respective responsibilities and work together.

Six priorities are identified for this mission:

- consolidation of PPPs to improve dialogue and cooperation among scientific/technological communities, stakeholders and policymakers in the fields of DRR and CCA;
- institutionalising community engagement for preparedness, response and recovery, by enhancing the appropriate knowledge to raise awareness and empowering community-based organisations and NGOs to engage and share knowledge, including volunteers' integration into emergency response activities and professionals' involvement into the planning and design prevention and reconstruction measures;
- strengthening the DRR/CCA media landscape through innovative use of traditional and emerging media, investigating the potential of new communication tools and apps for better preparedness and response;
- introducing novel governance approaches supported by transnational agreements based on local expertise and experience covering all phases of DRM for specific hazards involving multiple EU states;
- establishing an EU natural hazards research network for risk governance to provide support to DGs and JRC-DRMKC activities, while interacting with the UN-level entities to identify effective resilience pathways bridging DRR and CCA with SDGs;
- developing new governance strategies and robust decision-support methodologies, especially for contexts characterised by stakeholder conflicts, value differences (e.g. on who pays and who benefits from risk management decisions) and increasing social complexity.

Expected impact

The expected impact of the action includes:

- increase the cooperation between institutional and private bodies, ensuring that the necessary legal frameworks for sharing liabilities (e.g. unexpected events, unreliable information, evacuation, etc.) and for harmonized risk/hazard assessments and management are available;
- improve community participation and decision making in DRM, while gaining a better understanding of the societal aspects of disaster preparedness, response and recovery;
- build a risk-informed society, including educational programmes for youths and measures that also reduce inequalities within impacted communities that are related to specific issues such as migration, gender, age and disabilities;

85 http://www.naturalhazardspartnership.org.uk

- guarantee international cooperation and mutual assistance on task-specific issues (e.g. clustering hazard-specific transnational initiatives) and harmonizing the EUCPM capacities across countries;

- better integration of research activities at the EU and UN levels and taking advantage of ongoing initiatives such as the UNISDR Science and Technology Advisory Group [86], IRDR Integrated Research on Disaster Risk [87], and JRC-DRMKC to provide high level inputs for research and innovation in DRR and CCA.

4.6 MISSION 4. Overcoming the implementation gap in DRR and CCA

Specific mission

Observed institutional, operational and research gaps undermine the effective implementation of DRR and CCA measures in the EU. Even if DRR and CCA are considered as overarching principles in essential EU funding instruments such as the ESF, CAP and ERDF, and specific strategies for integration between sectors are in place, the two areas still remain in some cases siloed in legal and governmental frameworks. This often results in an uncoordinated implementation process. Effective coordination that embraces a comprehensive resilience agenda is essential to promote a resilience-based approach to territorial/urban planning and design, where an "all-hazards" approach in new developments, regeneration and retrofitting should result in a more effective allocation of financial resources and deliver multiple co-benefits to local communities.

New frontiers of research in this domain should investigate integrated DRR and CCA measures, fostering innovative knowledge sharing approaches, funding allocation mechanisms, legal instruments and operative measures. At the national and local levels, major investments should be supported by interdisciplinary research activities and practical applications, focusing at the same time on the exploitation of new technologies and nature-based solutions to increase the resilience of buildings and infrastructure. There is need for interdisciplinary research that addresses the institutional and organisational (formal and informal) barriers to effective coordination. These activities should include exploring alternative measures for incentivising private and public-private investments to help develop and implement novel solutions that target prevention, preparedness, response and recovery, and that bridge resilient design and Build Back Better concepts. Benefits and trade-offs of integrated measures should shift from the current experimental phase to widespread implementation by acting at national/local levels, involving local authorities, enterprises, professionals, households and communities at large. This would allow means of incentivising and engaging effective partnerships that include public and private sector, civil society, communities and individuals in delivering the required solutions to be identified.

Action

Possible future research approaches will address the need of an improved collaboration and integration between CCA and DRR fields to overcome the implementation gap in resilience investments. The action should address the identification and evaluation of concepts and tools to support novel approaches in urban planning, building and infrastructures design (both for new developments and retrofitting) characterized by a reasonable return of investments and favourable cost-benefit ratios, as well as achieving multiple benefits in the context of a comprehensive resilience agenda.

The following priorities have been identified:

- improve CCA and DRR integration by promoting the establishment of dedicated agencies at the national and sub-national level, avoiding the duplication of efforts and the competition for resources and administrative inefficiencies;

- foster DRR and CCA integration in planning activities within a multi-hazard and multi-scale perspective (regional to local, city to neighbourhood, etc.), identifying high/low-impact areas for development planning (limit urban growth; manage densification patterns; identify mid- to long-term resilience pathways);

- increase the resilience of buildings and infrastructure through "adaptive mitigation" design principles, providing effective disaster risk mitigation solutions that concurrently include climate adaptation;

- improve flexibility and adaptability of standards and regulations by leveraging joint public-private investments in novel adaptation solutions;
- integration of resilience into planning and

86 https://www.unisdr.org/partners/academia-research
87 http://www.irdrinternational.org/

design of new build, and Build Back Better when planning and designing for reconstruction, identifying funding arrangements to better link prevention and recovery;

- maximise the application of innovative and ecosystem-based solutions for enhancement of resilience (prevention) and the recovery of urban areas, with a specific focus on metropolitan cities, fragile natural landscapes and historic centres;
- explore and measure the multiple social, economic, environmental liveability benefits in terms of enhanced resilience of actions on climate mitigation and adaptation.

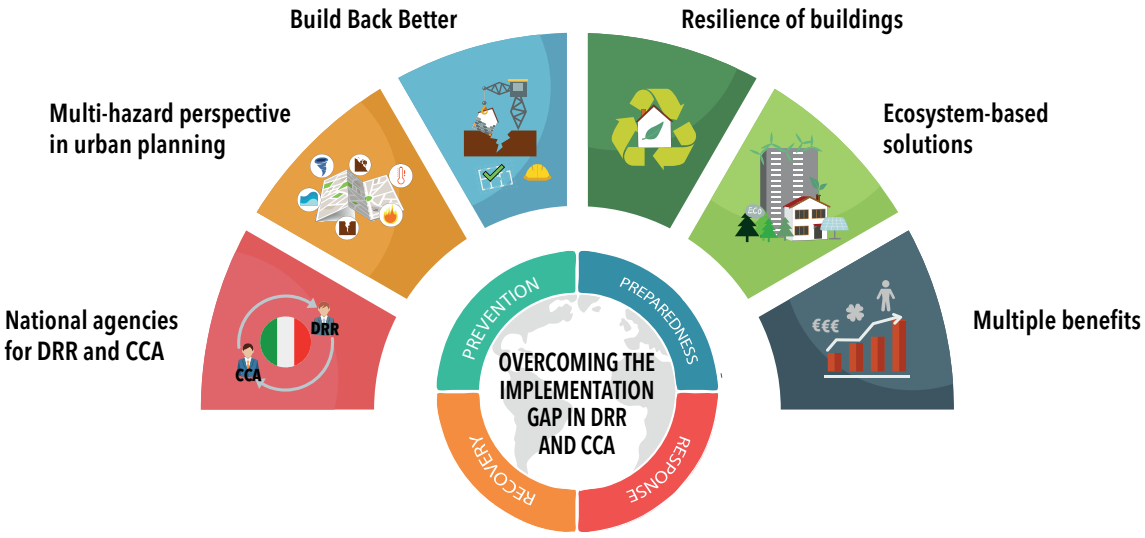

Figure 13: *MISSION 4. Overcoming the implementation gap in DRR and CCA*

Expected impact
The expected impact of the action includes:

- greater communication and coordination between responsible governmental authorities and between the scientists, decision-makers and practitioners, which will also lead to a more beneficial balance among investments;
- improve the key role of cities as facilitators of change, demonstrating through e.g. multi-criteria and cost-benefit analyses, the multiple benefits connected to the implementation of resilience measures in the built environment, while also considering the benefits obtainable outside of crisis periods;
- better linkage between climate, hazard and impact modelling with design planning activities, while identifying novel protocols, guidelines and standards for resilient designs suited to the EU context, based on integrated multi-risk reduction and climate change measures;
- exploring new methods to co-develop and assess alternative resilient planning and design solutions with decision- and policy-makers;
- improve the interactions between the risk sciences with building sector professionals (urbanists, architects, civil engineers and contractors) to promote the widespread adoption of resilient design principles;
- consolidate best practices for resilience-based urban regeneration and building retrofitting by formulating and enforcing novel regulation and incentive mechanisms.

4.7 MISSION 5. Human behaviour and disaster risk

Specific mission
Human actions and behaviour may strongly influence the effects and dynamics of a disaster and on the response. Prior to an event, poor land-use planning can, for example, lead to a heightened vulnerability of the population. Illegal constructions and low maintenance of critical infrastructures can, for example, lead to their collapse in a hazard event. Inadequate design of technological systems can, for example, favour cascading consequences due to human error, and insufficient planning, training and awareness in the affected communities will hamper response efforts.

During an event the behaviour of individual decision makers can strongly influence the physical and economic consequences of the event, while the behaviour of general public – mostly influenced by demographic factors (e.g. gender, age, income, risk-tolerance, social connectivity, etc.) and the perception of risk (e.g. intuitive risk judgements) – depends on availability and access to information about the crisis (Where did it happen? How dangerous is it? How quickly is it going to spread? etc.) which if limited, can endanger critical emergency measures, such as mandatory evacuation.

Most of the analyses of human behaviour in crisis situations carried out at European level are related to a specific event or to a specific behaviour. It is necessary to better investigate how emotional factors (e.g. anxiety, panic, etc.), during a disaster, influence rational actions, evaluations of options and information seeking.

Despite the shortcomings of many public authorities and crisis managers in handling disaster response, the high psychological demands that large-scale crises and disasters put on them have to be considered. Public authorities and crisis managers are confronted with a variety of stressors relating to high demands relating to operation and organisational activities and environmental factors (e.g. time pressure, level of risk). Due to extreme time pressure, crisis managers are often forced to make decisions an inadequate basis of information.

In the aftermath of a disaster event, during the recovery and reconstruction phase, human behaviour is mostly linked to the sense of disorientation, loss, resignation, protection of goods, fear for profiteering, etc. In this sense the recovery of local identity, daily life, services of citizens, are strictly linked to the nature of the event and to its magnitude. Research should also aim to understand time and modality of how disaster events consequences, as well as actions taken during response and recovery phases, can affect human relations, mental health, identity (and sense of place) and culture.

Action
The following priorities have been identified:

- Develop qualitative and quantitative analyses on the behaviour of diverse society groups affected by a natural hazard, before, during and after an event occurs;
- Develop analyses on human behaviour as triggering or cascading factors of disasters caused by natural events;
- Transform qualitative analysis data into quantitative information to improve vulnerability and exposure analyses;
- Identify specific measures to better address the needs and requirements of most vulnerable groups (chronic suffers, persons with disabilities, children, elders, etc.) in emergency planning and recovery measures;
- Investigate the nature and scope of mental health issues arising during and following extreme events and disasters caused by natural events and their implications for response and recovery, and explore options for addressing these issues, including through social and health services;
- Develop and explore the efficacy of innovative information tools and smart management cockpits, from both formal, authoritative (e.g. news media, government and employers) and informal sources (e.g. pre-established or event specific social networks, citizens as distributed sensors);
- Investigate the specific stress factors that affect emergency managers and governmental authorities and how these factors affect their thinking and managing skills during disaster response, and explore options for addressing this;
- Investigate mechanisms and factors (inhibitions, lack of time, pressure, disinformation etc.) that can lead to false alarms and misdirected actions, and the direct consequences on both population and decision-makers;
- Investigate the consequences of diverse and multiple natural events on human perception of spaces, history, culture and symbols (including cultural heritage, intangible and relational values, etc.).

Expected impact
The expected impact of the action includes:

- Full inclusion of behavioural science and human factors perspective in disaster risk/impact analysis/sectoral modelling ("comprehensive approach");
- Building an all-in society approach to disasters caused by natural events, including most vulnerable groups of the society;
- Increased awareness and risk informed society through new information technologies, semantic web, Internet of Things and the inclusion of the concept of monitoring and alert in daily life tools;
- Training and simulations (also through gaming activities) for decision makers and emergency manager to improve their capabilities, including their capabilities to manage stress factors during a disaster response;
- Promote culture-related behaviours and local capacity to face post-disaster reconstruction and rehabilitation.

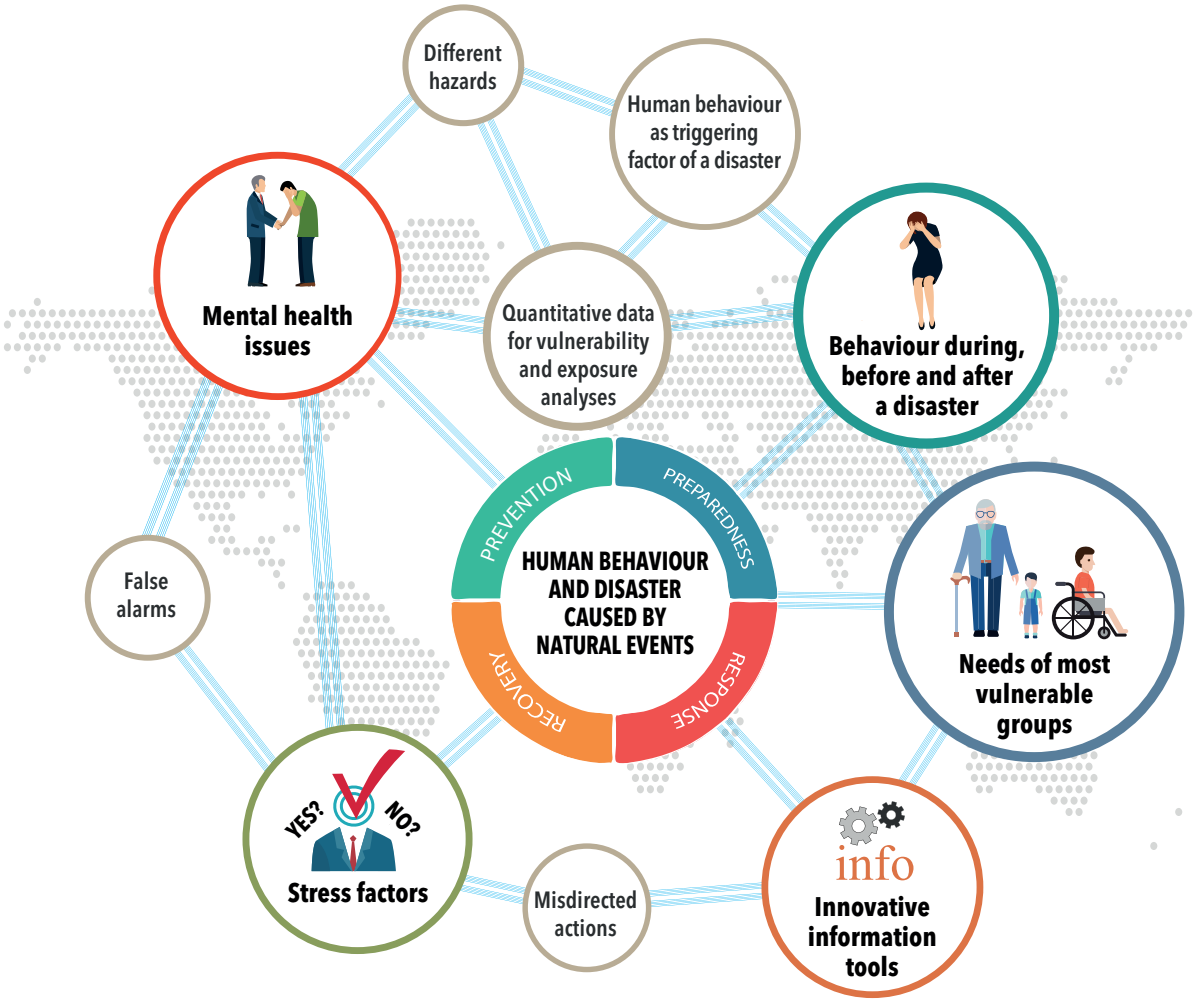

Figure 14: *MISSION 5. Human behaviour and disaster risk*

References

Antofie, T. E., Doherty, B., Marin Ferrer, M., (2018) Mapping of risk web-platforms and risk data: collection of good practices, EUR 29086 EN, Publications Office of the European Union, 2018, ISBN 978- 92-79-80171-6, doi:10.2760/93157, PUBSY No. JRC109146. Available at: https://ec.europa.eu/jrc/en/publication/mapping-risk-web-platforms-and-risk-data-collection-good-practices

Appulo, L., Paszkowski, J., Rossi, L., Alarslan, E., Attolico, A., Ezgi Baksi, E., Guarino, G., Hearn, M., Karantanellis, E., Leone, M., Zuccaro, G. (2017) Technical Session 2: Land-use planning and management practices at the local level, EFDRR Open Forum Istanbul, Turkey 26-28 March 2017 accessed at: http://efdrrturkey.org/upload/files/Documents/2017EFDRR-TS2-ConceptNote.pdf

Boin A., Myrdal, S., Ekengren. M, Rhinard, M. (2009) Preparing for Transboundary Threats: What Role for the Next European Commission? Policy brief published with the European Policy Centre (EPC), Brussels. Available at: http://www.epc.eu/pub_details.php?cat_id=3&pub_id=478

Capela Lourenço, T., Rovisco, A., Groot, A., Nilsson, C., Füssel, H., Van Bree, L., Street, E.D., eds. (2014) Adapting to an Uncertain Climate: Lessons From Practice. DOI 10.1007/978-3-319-04876-5_4, Springer International Publishing Switzerland

De Groeve, T., Al Khudhairy, D., Annunziato, A., Broad, A., Clark, I., Bower, A. (2015) Surveying the landscape of science/policy interfaces for disaster risk management policy making and operations EUR 27508, Publication Office of the European Union, Luxembourg, JRC93041. Verfügbar unter: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/surveying-landscape-sciencepolicy-interfaces-disaster-risk-management-policy-making-and

ENHANCE Project (2015) Partnerships are affordable and equitable policy instruments for disaster risk reduction. Available at: http://www.enhanceproject.eu/uploads/biblio/document/file/70/15_03_MF_ENHANCE_BOOKLET_V2_updated.pdf

ESPREssO Project (2017) Overcoming obstacles for disaster prevention: Challenges and best practices from the EU and beyond. Available at: http://www.espressoproject.eu/images/deliverables/ESPREssO_D2.2_FINAL.pdf

ESPREssO Project (2018a) Proposal of solutions to overcome the three ESPREssO challenges. Available at: http://www.espressoproject.eu/images/deliverables/ESPREssO_D4.7_final.pdf

ESPREssO Project (2018b) Report on existing methodologies for scenario development and stakeholders knowledge elicitation. Available at: http://www.espressoproject.eu/images/deliverables/ESPREssO_D3.2.pdf

ESPREssO Project (2018c) Stakeholder Engagement process - understanding stakeholders needs, perspectives and opinions, and identifying the priorities of stakeholders for innovation.

European Commission (2010) Commission Staff Working Paper Risk Assessment and Mapping Guidelines for Disaster Management, Brussels, 21.12.2010 SWD (2010) 1626 final. Available at: https://ec.europa.eu/echo/files/about/COMM_PDF_SEC_2010_1626_F_staff_working_document_en.pdf

European Commission (2013) Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32013D1313

European Commission (2015) Commission notice Risk Management Capability Assessment Guidelines. Brussels, 2015/C 261/03. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2015.261.01.0005.01.ENG

European Commission (2016a) Climate Action Paris Agreement from European Commission. Available at: http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm

European Commission (2016b) Commission Staff Working Document Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030, Brussels, 17.06.2016 SWD (2016) 205 final. Available at: http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf

European Commission (2017) Commission Staff Working Document Overview of Natural and Man-made Disaster Risks the European Union may face. Brussels, 23.5.2017 SWD (2017) 176 final. Available at: http://ec.europa.eu/echo/sites/echo-site/files/swd_2017_176_overview_of_risks_2.pdf

European Commission (2018) Directorate-General for Research and Innovation Mission-oriented research & innovation in the European Union Available at: https://publications.europa.eu/en/publication-detail/-/publication/5b2811d1-16be-11e8-9253-01aa75ed71a1/language-en

European Environment Agency (2017) EEA Report No 15/2017 Climate change adaptation and disaster risk reduction in Europe. Available at: https://www.eea.europa.eu/publications/climate-change-adaptation-and-disaster

European Environment Agency (2018) National Climate Change Vulnerability and Risk Assessments in Europe. Available at: https://www.eea.europa.eu/publications/national-climate-change-vulnerability-2018

IPCC (2014a) Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC (2014b) Fifth Assessment Report. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Annex II – Glossary. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-AnnexII_FINAL.pdf

Karali, E., Mysiak, Y., Castellari, S., Swart, Schwarze, R., Buontempo, C. (2018) a Climate services for disaster risk reduction: workshop notes, Bologna. Available at: https://www.placard-network.eu/climate-services-for-disaster-risk-reduction/

Marin Ferrer, M., Casajus Valles, A. (2018) Workshop on Risk Management Capability Assessment, EUR 29135 EN, European Commission, Ispra, JRC110784. Available at: https://ec.europa.eu/jrc/en/publication/workshop-risk-management-capability-assessment

Marin Ferrer, M.; Do Ó, A.; Poljansek, K., Casajus Vallés, A. (2018) Disaster Damages and Loss Data for Policy: Pre- and Post-event damage assessment and collection of Data for Evidence-based policies, Publication Office of the European Union, Luxembourg, JRC110366. Available at: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/disaster-damages-and-loss-data-policy-pre-and-post-event-damage-assessment-and-collection

Mysiak, Y., Castellari, S., Kurnik, B., Swart, R., Pringle, P., Schwarze, R., Wolters, H., Jeuken A., and van der Linden, P. (2018) Brief communication: Strengthening coherence between climate change adaptation and disaster risk reduction through policies, methods and practices in Europe, Natural hazards and earth system sciences – an interactive open-access journal of the European Geosciences Union, Copernicus Publications. Available at: https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-80/

Mysiak, J., S. Surminski, A. Thieken, R. Mechler, and J. Aerts (2016) Brief communication: Sendai framework for disaster risk reduction—Success or warning sign for Paris? Natural hazards and earth system sciences – an interactive open-access journal of the European Geosciences Union, Copernicus Publications. Available at: https://www.nat-hazards-earth-syst-sci.net/16/2189/2016/

Poljanšek, K., Marin Ferrer, M., De Groeve, T., Clark, I., (Eds.) (2017) Science for disaster risk management 2017: knowing better and losing less. EUR 28034 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-60679-3, doi:10.2788/842809, JRC102482. Available at: https://ec.europa.eu/jrc/en/publication/science-disaster-risk-management-2017-knowing-better-and-losing-less

Rios Diaz, F., Marin Ferrer, M. (2018) Loss Database Architecture for Disaster Risk Management EUR 29063 EN, Publication Office of the European Union, Luxembourg, JRC110489. Available at: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/loss-database-architecture-disaster-risk-management

UN (2005) Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters. Available at: http://www.preventionweb.net/files/1037_hyogoframeworkforactionenglish.pdf

UNDESA (2015) Sustainable development goals. Available at: http://www.un.org/en/development/desa/categories/sustainable.html

UNECE (2009) Transboundary Flood Risk Management: Experiences from the UNECE region. Geneva and New York. Available at: https://www.unece.org/index.php?id=11654

UNECE (2017) Cross-border concerns, shared strategies. Geneva. Available at: http://www.unece.org/environmental-policy/conventions/industrial-accidents/publications/official-publications/2017/cross-border-concerns-shared-strategies/docs.html

UNFCCC (2016) Paris Agreement. Available at: http://unfccc.int/paris_agreement/items/9485.php

UNHABITAT (2011) Cities and Climate Change: Global Report on Human Settlements 2011. Malta: Gutenberg Press

UNISDR (2011) GAR 2011 Global Assessment Report on Disaster Risk Reduction, Revealing Risk, Development. Geneva. United Nations International Strategy for Disaster Reduction Secretariat. Available at: https://www.unisdr.org/we/inform/publications/19846

UNISDR (2012) How to make cities more resilient: a handbook for local government leaders. Geneva. Available at: https://www.unisdr.org/we/inform/publications/26462

UNISDR (2015) The Sendai Framework for Disaster Risk Reduction 2015-2030. Available at: http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

UNISDR (2015a) Reading the Sendai Framework for Disaster Risk Reduction 2015-2030. Available at: https://www.unisdr.org/we/inform/publications/46694

UNISDR EUR (2016) European Forum for Disaster Risk Reduction (EFDRR) Roadmap 2015-2020. Available at: https://www.unisdr.org/we/inform/publications/55096

UNISDR (2017) Words into Action Guideline: National disaster risk assessments - Governance System, Methodologies, and Use of Results-, Issued October 2017. Available at: http://www.preventionweb.net/files/52828_nationaldisasterriskassessmentwiagu.pdf

UNISDR (2017a) Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. Available at: https://www.unisdr.org/we/inform/publications/51748

World Economic Forum (2018) The Global Risks Report 2018, 13th Edition. Available at: http://reports.weforum.org/global-risks-2018/

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Rawpixel.com - Freepik.com (https://www.freepik.com/free-vector/illustration-set-of-environmentally-icons_2805929.htm)
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Photoroyalty - Freepik.com (https://www.freepik.com/free-vector/social-networking-connections_957338.htm)
Sapann-Design - Freepik.com (https://www.freepik.com/free-vector/transport-of-patients-in-a-hospital_957634.htm)

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