EU-CIRCLE

A pan-European framework for strengthening Critical Infrastructure resilience to climate change

D9.6 Awareness and wider societal implications

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Public Deliverable

Statement
This deliverable presents the societal and awareness implications of EU-CIRCLE during the 2nd reporting of the project. The project demonstrated a multi-dimensional impact for 1) protecting CI & societies from adverse climate change impacts, 2) Policy shifts towards resilience based adaptation, 3) Performing localised impact and resilience assessment, 4) awareness raising activities and 5) contribute to innovation growth.

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Executive Summary

Modern societies are heavily dependent on critical infrastructure to provide essential services (energy, transport, water, sewage, telecoms, chemical and fuels). CI are systems that are dependent and interdependent, on many other systems and failure of one often leads to cascading failures. The EU-CIRCLE project developed and demonstrated the validity in real case studies a holistic framework for enhancing resilience of Critical Infrastructures against climate hazards and extreme weather events which are expected to exacerbate with climate change.

Within the project duration, the consortium believes that the project had the following societal and awareness impacts:

EU-CIRCLE societal impact 1: Protecting CI & societies from adverse climate change impacts.

CI have a critical role in maintaining smooth societal functioning and contribute healthy cities, energy poverty and the wellbeing of the population. Furthermore, resilient CI that are able to resist and/or quickly recover from climate hazards are critical components of emergency management and thus their availability is a matter of societal resiliency. Central to this, was putting the “service continuum” of the CI as the high level conceptual approach and building the CI climate change risk and resilience framework around it.

Owing to climate change CI are exposed to multitude of adverse climate conditions, which could be intensification of existing ones or even appearance of new climate threats in areas never seen before. During the project duration Europe faced significant hazards, directly associated with the project’s case studies, such as intensifying forest fires in the South (66 dead in Portugal 2017, 99 dead in Greece 2018) and appearances in North Europe (Germany 2018, Sweden 2018), storms in the UK (Emma in March 2018), drought in Central Europe (summer 2018). Thus when climate change risk assessment studies are to be conducted, the recommendation is to think “out of the box” in terms of potential hazards.

EU-CIRCLE societal impact 2: Promoting policy shifts to resilience based adaptation.

In order to enhance the resilience of CI to climate threats, the project investigated the possibility for a policy shift for climate change adaptation and/or disaster risk reduction. The project examined through numerous discussions with the Stakeholders Advisory Group and also in the conduction of the case studies the benefits arising from using resilience as a high level overarching policy to compliment cost benefit analysis. WP4 presents a comprehensive theoretical framework on how to achieve this objective.

EU-CIRCLE societal impact 3: localized impact & resilience assessment.

The EU-CIRCLE resilience framework has been proposed as a versatile approach, that can be adapted and implemented at different levels, from the single CI asset, to the CI network and the network of networks within a city / region. In this process, the impacts to society and the environment are an integral part. The versatility of the framework has been demonstrated in the five case studies where localised hazard, impact assessments and resilience estimation have been provided. Since all case studies have been conducted with the enthusiastic participation of local stakeholders (not project partners) then the project is well positioned to have an impact on local society

EU-CIRCLE societal impact 4: Awareness raising activities

EU-CIRCLE, from its conception placed high importance on awareness raising activities. To this extend a multi-dimensional set of activities have been designed and implemented. The activities were directed towards the CI stakeholders, national and regional authorities, meteorologists and climatologists, academic and research communities, industries and of course the general public. In brief, these include:

- Dissemination actions, that are extensively described in D8.5 and D8.6 for the two project periods respectively. Overall, the project achieved dissemination targets set in the DoA.

- Training material is prepared that will allow the project partners and the community to gain insights and promote the implementation of CI climate resilience to stakeholders and educate the next generations, especially give the worldwide trend to establish “resilience engineering” courses.
- EU-CIRCLE participated in four events that were under the auspices of the EU (DRMKC, CoU, JRC resilience workshop) and established synergies with numerous projects (e.g. Common Dissemination Booster) and international initiatives.

EU-CIRCLE societal impact 5: Contribution to innovation growth

The project, although a Research and Innovation Action, made consolidated efforts to contribute to competiveness and innovation growth. The main actions towards this were

- Establish and implement a unique exploitation model (final version presented in Deliverable D8.13) that projects tools, data and solutions could be presented to potential customrs.
- Proposed, developed and tested a series of tools that account for the multi-dimensionality of CI climate change resilience. These include the Critical Infrastructure Resilience Platform (CIRP), the Resilience Assessment Tool (RAT), Asset Class Repository (ACR), hazard simulation and visualization tools. Also the virtual data set (Deliverable D7.4) with CI data and reference hazards has been made available to the stakeholder and academic community.
- EU-CIRCLE created multiple climate data and hazard simulations in support to the case studies. These have been gradually and will continue in the coming period to be made available to the community through the climate services initiative.
- Finally, EU-CIRCLE attempted to establish metadata standards in support of orchestrating the different and diverse models that were used. A complete metadata standards suite has been used from climate and hazards (D2.4) to CI description and risk assessment (D3.6) and resilience (D4.8). Collectively these have been presented in D8.11 and have been submitted for consideration to Open Geospatial Consortium - OGC.

Contents

1 Introduction

The scope of this Deliverable is referred to record, classify and assess the societal and awareness raising implications of EU-CIRCLE during its project duration. As such, and following reference from EU document "Horizon 2020 indicators. Assessing the results and impact of Horizon"[1], and the DoA, the project engaged in multiple societal and awareness raising activities. The categorization of theses, has been made in order to reflect general categories, adding specific ones pertaining to the needs of the project. These include: 1) relevant to enhancing innovation capacities and market opportunities, 2) addressing the societal need for resilient CI to climate change that will support the society to grow and bounce back from major disasters, 3) adapt to climate change, 4) awareness raising to the general public and CI stakeholders.

The deliverable was compiled using desktop research to provide statistical support to findings and discussions and exchange of opinions between the partners. Specifically, the most recent literature on the subject has been investigated as well as the results from other relevant research projects. Also, special attention was paid to the European Union legislation and working documents of the European Commission, and especially the impact assessment reports.

Moreover, a top-down approach was implemented, starting from the overall problem of societal impacts of climate change in Europe and focusing on the issues generated directly by climate change to critical infrastructures and indirectly to overall socio-economic context. Thereafter, the main socio-economic impacts occurred by the EU-CIRCLE Holistic Resilience Framework implementation recorded and classified. Special mention should be made on the interaction of end users.

[1] DG RTD, "Horizon 2020 indicators - Assessing the results and impact of Horizon", Brussels 2015, ISBN 978-92-79-49477-2 doi:10.2777/98003

2 EU-CIRCLE societal impact 1: Protecting CI & societies from adverse climate change impacts.

CI have a critical role in maintaining smooth societal functioning and contribute healthy cities, energy poverty and the wellbeing of the population. Furthermore, resilient CI that are able to resist and/or quickly recover from climate hazards are critical components of emergency management and thus their availability is a matter of societal resiliency. Central to this, was putting the "service continuum" of the CI as the high level conceptual approach and building the CI climate change risk and resilience framework around it.

2.1 Societal impact 1.1: The role of CI in modern societies

Climate related hazards have the potential to substantially affect the lifespan and effectiveness or even destroy of European Critical Infrastructures (CI), particularly the energy, transportation sectors, buildings, marine and water management infrastructure with devastating impacts in EU appraising the social and economic losses. However, in order to understand the vast impact one has to establish the European context of CI role in modern societies and economy.

2.1.1 Setting the European context

"Critical infrastructure is an asset or system which is essential for the maintenance of vital societal functions. The damage to a critical infrastructure, its destruction or disruption by natural disasters, […], may have a significant negative impact for the security of the EU and the well-being of its citizens."[2]. Within EU-CIRCLE, the CI networks of interest have been identified in D1.3 and analysed in terms of their assets in D3.1 Registry with CI Assets and Interconnections. Over the next paragraphs a short analysis of the importance of CI is elaborated.

2.1.2 Energy

The vital role of energy in Europe it is widely acknowledged. Electricity, Oil, Gas, Renewables etc supply the vast majority of economic sectors and households. The sustainability of the Energy Networks as well as their resilience is of the highest priorities. The figures below introduce the EU wide consumption and generation of electricity in the EU

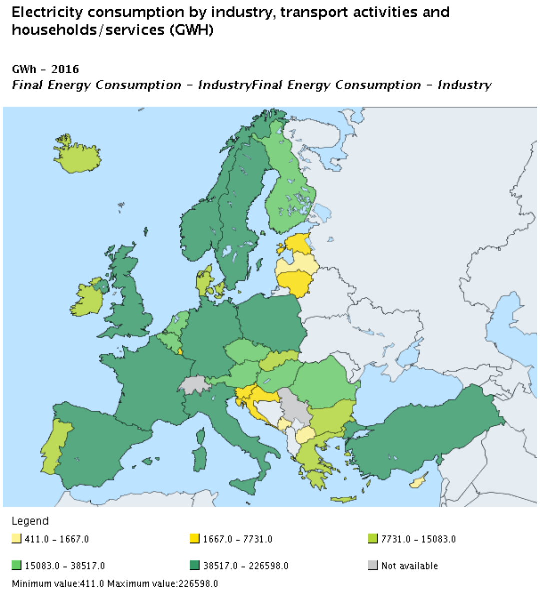


Figure 1: Electricity consumption by industry, Eurostat

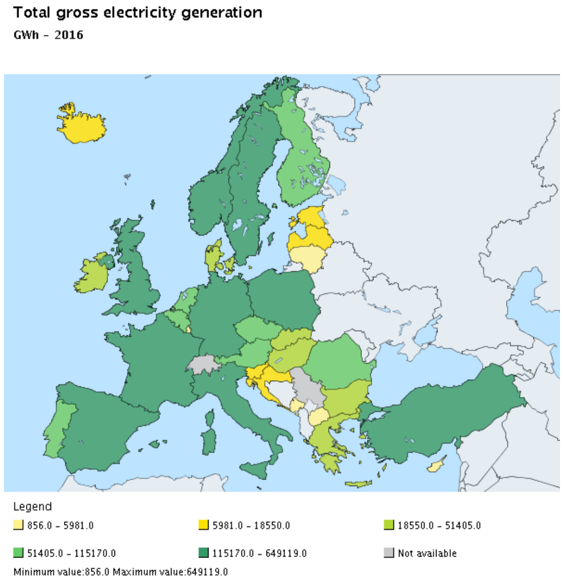


Figure 2: Total gross electricity generation, Eurostat

[2] https://ec.europa.eu/home-affairs/what-we-do/policies/crisis-and-terrorism/critical-infrastructure_en

The energy sector faces multiple impacts from changing climate, with the most important ones identified as extreme weather events and increasing stress on water resources. Greater resilience to climate change impacts will be essential to the viability of the energy sector and its ability to cost-effectively meet the rising energy demands driven by global economic and population growth. The energy sector is also pivotal to the analysis as it is virtually interconnected to every other sector of critical infrastructure and key to the well-being of modern societies. In the context of the electricity power system, strategic risk issues the electricity sector but cascade to other critical infrastructures.

2.1.3 Transportation

Transportation networks have been developed rapidly through last decades. Transportation infrastructure has played very important role in the Europe's economic growth and development and is one of the pillars of European production and communication.

Figure 3: Air Transport of goods, Eurostat

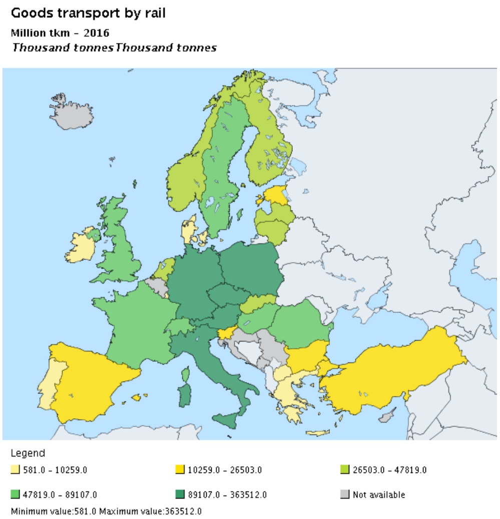


Figure 4: Goods transport by rail

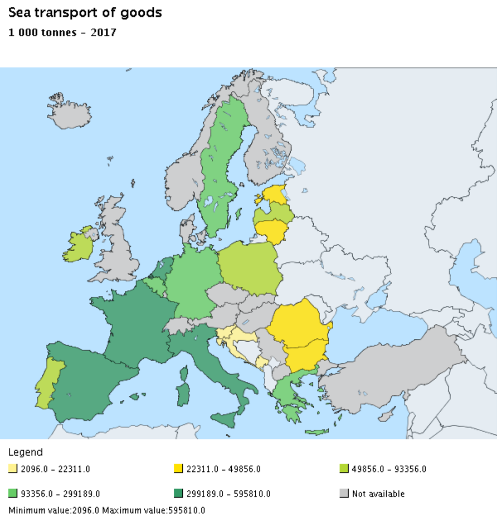


Figure 5: Sea transport of goods, Eurostat

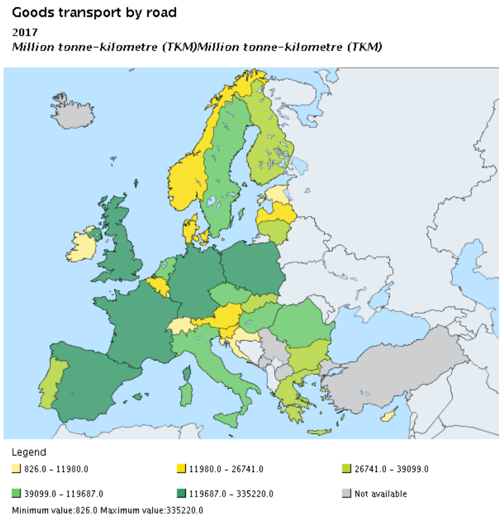


Figure 6: Goods transport by road, Eurostat

The impact of climate change and sea level rise on transport has received qualitative, but limited quantitative, focus in the published literature. The impact depends greatly on the climatic zone the infrastructure is in and how climate change will manifest itself. The transportation sector will be probably under threat from projected climate change. The rail sector has a high probability of being impacted by temperatures and extended heatwave periods especially for rail buckling, pavement deterioration and thermal comfort for passengers in vehicles. Extreme weather events will likely impact both the integrity of infrastructures and travel times due to interruptions and delays. Maritime transportation could be under threat from sea-level rise (harbours and other infrastructure).

2.1.4 Water

Climate change will potentially impact with varying scale and intensity the water supply infrastructure and water demand. Economic impacts shall be substantial and will likely include flooding, scarcity, and cross-sectoral competition. Flooding can have major economic costs, both in term of impacts (capital destruction, disruption) and adaptation (construction, defensive investment). Water scarcity and competition for water driven by institutional, economic, or social factors may mean that water may not be in sufficient quantity or quality for some uses or locations

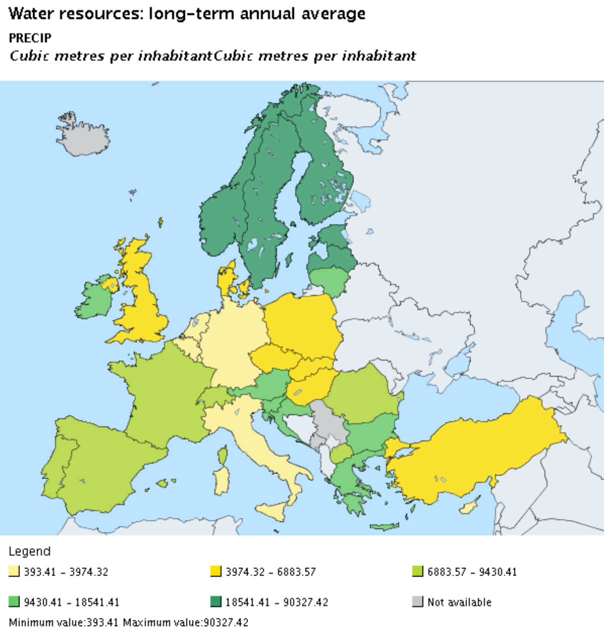


Figure 7: Water resources per inhabitant, Eurostat

2.1.5 ICT

The information & communications sector has been relatively resilient to climate change and in normal operation less sensitive to climatic conditions. The sector itself is mainly prone to cascade effects from climate hazards due to major dependencies on other sectors that include energy, transportation, water and logistics and thus is critical to the identification of dependencies and interdependencies of CI. Loss of telecommunication access during extreme weather events can inhibit disaster response and recovery efforts because of its critical role in providing logistical support for such activity. Several assets of communications networks are at risk due to extreme winds and/or flooding.

2.1.6 Chemical Industry

According to industry reports, the key climatic changes relevant to the operation of chemical plants include the impacts of extreme events to off-shore and coastal infrastructures such as a rise in sea levels, increased wave heights and storm surges, flooding, and tropical storms and cyclones. The impact of these risks for each project will be dependent on the location, facility type, facility design and expected life-time. Overall, the Chemical Sector’s major dependencies on other sectors include transportation (ports, rail, and truck), energy, communications and waterways

2.1.7 Overall statistics of Critical Infrastructure

Additionally to the above data, Table 1 introduces the Gross Value Added of the CI sectors in the EU context, and Table 2 the number of employees, which gives a picture of the importance of the CI not only to the functioning of European societies, but also as pylons of the economy and development. Thus the resilience of CI to climate threats, as proposed by EU-CIRCLE, could provide the CI stakeholders with additional tools to enhance their capacity to protect, “bounce back” and/or “build back better” to adverse conditions which will be exacerbated by climate change.

Table 1. CI sectors Gross Value Added (Domestic GVA in Million euros in EU, Source: EUROSTAT)

INDUSE/TIME	2012	2013	2014	2015
Chemicals and chemical products	307.965,33	309.812,62	320.833,99	345.908,38
Electricity, gas, steam and air conditioning	400.161,52	407.284,17	412.547,86	436.296,7
Natural water; water treatment and supply services	25.994,85	26.535,69	26.529,88	27.724,24
Land transport services and transport services via pipelines	282.396,8	284.421,87	288.533,59	304.218,16
Water transport services	69.629,15	78.053,81	78.441,63	82.340,08
Air transport services	74.836,67	76.072,42	76.138,18	82.728,79
Telecommunications services	175.647,15	168.862,29	174.369,72	186.366,06
Public administration and defence services; compulsory social security services	308.531,69	303.555,41	318.025,77	328.599,98

Table 2. Employment in CI sectors (Employment in Thousand Persons, in EU, Source: EUROSTAT)

NACE_R2/TIME	2012	2013	2014	2015
Electricity, gas, steam and air conditioning supply	1.647,4	1.644,2	1.537,4	1.589,1
Water supply; sewerage, waste management and remediation activities	1.695,9	1.651,2	1.682,5	1.670,2
Transportation and storage	11.000,8	11.078,0	11.199,0	11.407,1
Information and communication	6.423,4	6.251,7	6.442,6	6.608,0
Public administration and defence; compulsory social security	14.990,5	14.912,2	15.047,2	15.178,6

2.2 Societal impact 1.2: CI exposure to climate change threats

Owing to climate change CI are exposed to multitude of adverse climate conditions, which could be intensification of existing ones or even appearance of new climate threats in areas never seen before. During the project duration Europe faced significant hazards, directly associated with the project’s case studies, such as intensifying forest fires in the South (66 dead in Portugal 2017, 99 dead in Greece 2018) and appearances in North Europe (Germany 2018, Sweden 2018), storms in the UK (Emma in March 2018), drought in Central Europe (summer 2018). Thus when climate change risk assessment studies are to be conducted, the recommendation is to think “out of the box” in terms of potential hazards.

According to recent EC wide studies, (Forzieri et al, 2018) , there is an increasing trend in terms of CI exposed to climate related threats. The spatial and temporal dimensions of the impact vary considerably and thus localised exposure and vulnerability assessment studies should be performed at the most suitable level. According to the latest National Climate Change Risk Assessment by European counties (EEA, 2018) infrastructures such as energy, transport, industries and digital infrastructures are of high priority amongst EU countries. Concerning the National Risk Assessment Plans (SWD 176/2017) the impact of climate change on CI has been considered bringing Malta as a paradigm.

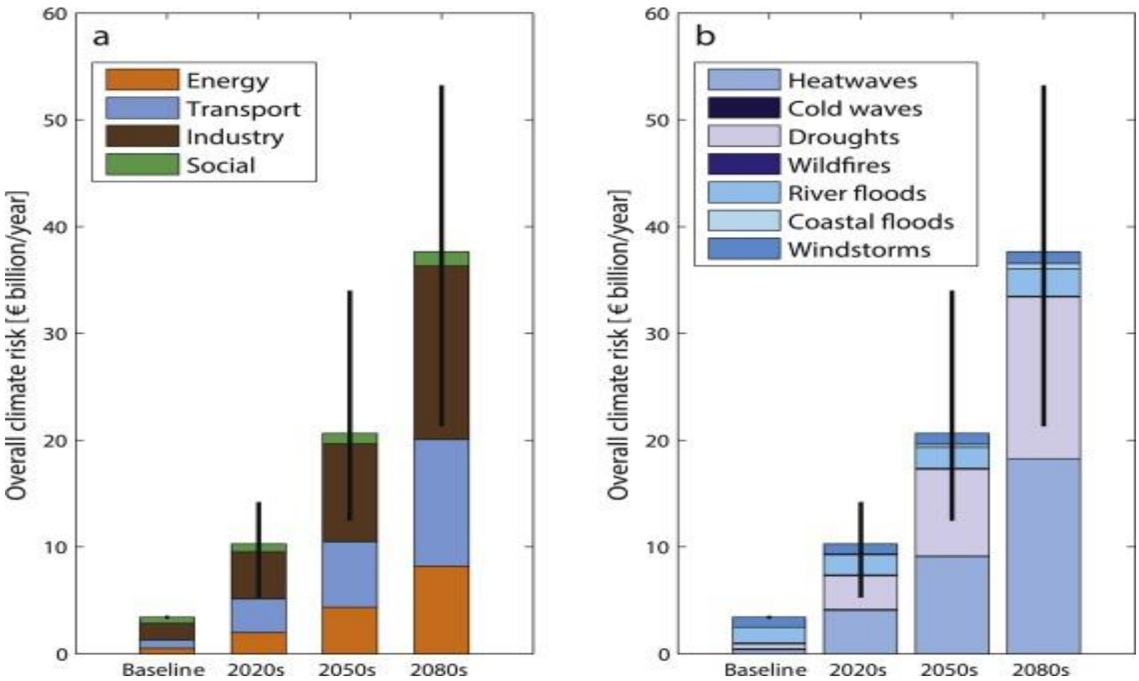


Figure 8: Overall climate hazard risk to critical infrastructures aggregated at European level (EU+) for each time period: a) distribution of damage by sector; b) distribution of damage over the seven hazards. For wind, projections of hazard are not available not available for 2020 s and 2050s; damage for these periods was obtained by linearly interpolating between the baseline and the 2080s. Whiskers reflect the inter-model climate variability. **Source:** G Forzieri et al, 2018

2.3 Societal impact 1.3: Climate change risk assessment to CI

2.3.1 Infrastructure Risks

The determination of the risk of Critical Infrastructure due to Climate Change is very important in order to assess the climate threats and their evolution. According to EU-CIRCLE findings, climate change is expected to bring varying levels of risks to CI for the following reasons:

- ✓ Changing nature of hazards. Certain hazards will likely appear in EU areas that have not be (such as prolonged drought in North Europe), where as the hazard could be appearing more frequent (e.g. flooding in SW UK) and evolving at a faster pace and be of higher magnitude (e.g. forest fires in South Europe).
- ✓ Higher levels of climate threats will in turn lead to the need to establish and/or modify design thresholds such as (EUROCODES). This finding has been repeatedly occurring in EU-CIRCLE's different case studies and is consistent with other similar findings e.g. for snow (Croce et al 2018).
- ✓ Increased vulnerability is expected to occur with a multitude of impacts for CIs and types of hazards. The various case studies determined different impacts, complementing existing literature, that can be classified as: structural damages mainly due to extreme events, impacts on employees (e.g. due to prolonged heatwaves), impacts on operational procedures and also how CI should adapt to respond to disasters.

2.3.2 Modelling risk within EU-CIRCLE

The EU-CIRCLE project proposed a variant of the Consequence – based Risk Management (CRM) process where different climate hazards (scenarios) can be examined corresponding to specific policy/scientific questions. As presented in D3.5, the EU-CIRCLE core methodology for quantifying the overall risk is based on a five class scale and a set of mixing rules. The "reaction" of CIs to a hazard is summed up to a set of indicators that have different units and meaning, depending on the case under study or the calculation the user desires. They can range from *the number of assets fully destroyed* to *total time that person is left without two or more CI services*. The difficulty is to unify the different indicators and assess the overall risk. The proposed methodology can be used for either a single or combined hazards (see paragraph **Error! Reference source not found.** & **Error! Reference source not found.** of D3.5).

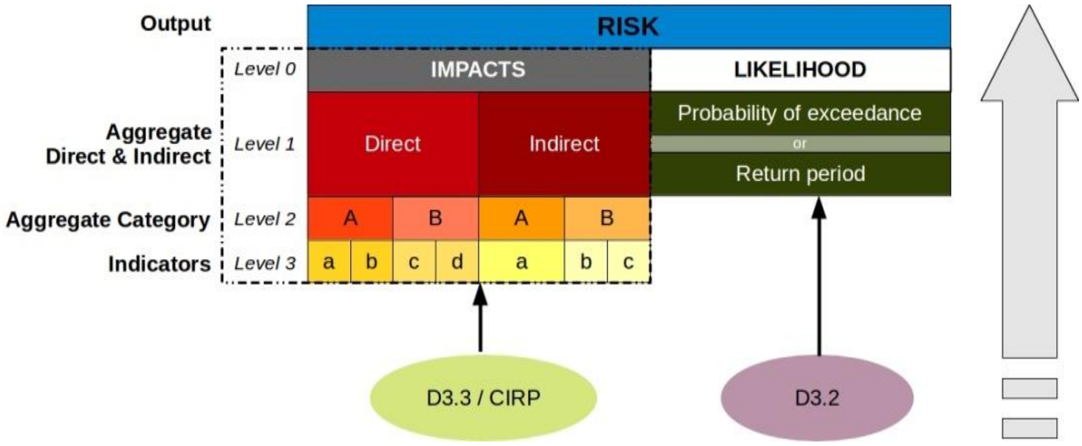
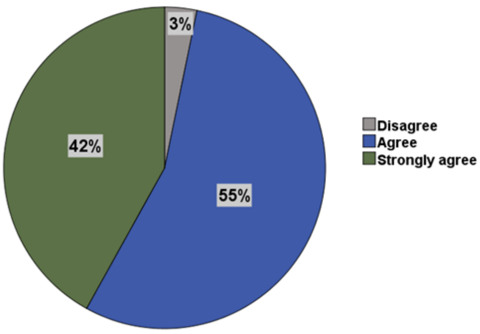


Figure 9 : Illustration of Risk assessment core methodology

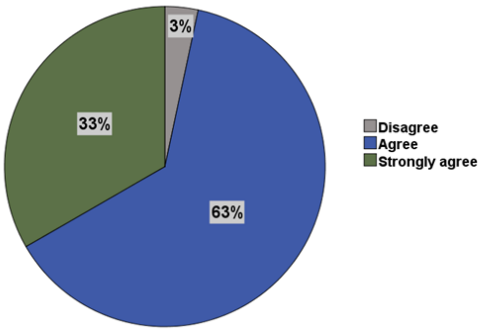
For modeling risk, EU-CIRCLE proposed **the Consequence – based Risk Management (CRM) generic approach**. The key advantage of this approach is that it uses an optimization-based prescriptive model of system operation as the starting point for the study of infrastructure behaviour: *these models inherently accommodate disruptions to infrastructure as straightforward changes to input data*.

2.4 Acceptance of EU-CIRCLE framework

The collective evaluation of the EU-CIRCLE framework, extensively presented in D6.12, based on the responses of stakeholders on all case studies provided a positive feedback on the capabilities and performance of the framework. The participants agreed that a) that EU-CIRCLE tools will speed up their processes for assessing risk due to climate change and estimating resilience level of their infrastructures and b) the reliability of the proposed tool is higher than existing ones;



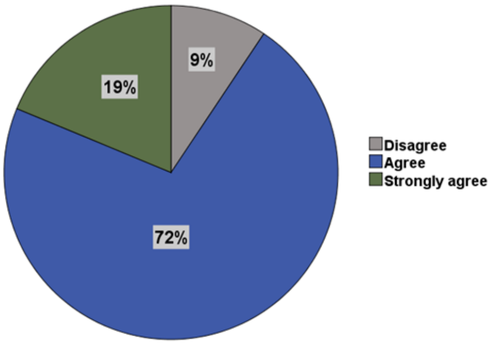
II.5.1. Using the EU-CIRCLE platform would enable me to assess risks more quickly than with my current methods.



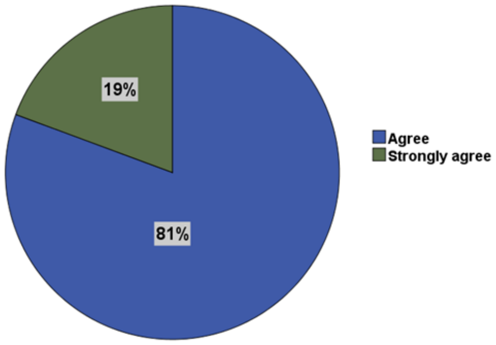
II.5.2. Using the EU-CIRCLE platform would enable me to define resilience more quickly than with my current methods.

Moreover, almost everyone agrees that EU-CIRCLE solution has in overall higher capabilities for performing scenarios with multi-risk assessment, integrating more hazards, ideally for mid- and long-term planning.

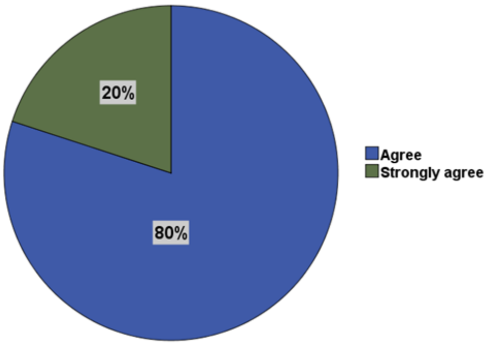
Finally, highly positive is the reaction with regards to the support EU-CIRCLE solution offers to relevant operators and stakeholders towards the improvement of risk management within the CI and resilience strengthening, with the total of respondents stating compliance of the risk and resilience outcome of EU-CIRCLE with their expectations, based on their experience.



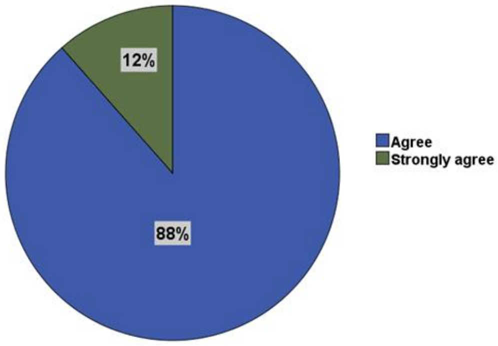
9. Using the EU-CIRCLE solution would help you to understand impacts originating from secondary effects (propagated consequences).



10.1. Using the EU-CIRCLE solution would enable you to manage risks more effectively than you can now



10.2. Using the EU-CIRCLE solution would enable you to strengthen resilience more effectively than you can now.



12.1. I find the EU-CIRCLE risk estimations to be very close to what I would expect from my experience

3 EU-CIRCLE societal impact 2: Promoting policy shifts to resilience based adaptation.

3.1 Societal impact 2.1: from risk to resilient assessment

In order to enhance the resilience of CI to climate threats, the project investigated the possibility for a policy shift for climate change adaptation and/or disaster risk reduction. The project examined through numerous discussions with the Stakeholders Advisory Group and also in the conduction of the case studies the benefits arising from using resilience as a high level overarching policy to compliment cost benefit analysis. WP4 presents a comprehensive theoretical framework on how to achieve this objective.

3.2 How EU-CIRCLE tackles the concept of resilience based adaptation

Critical infrastructure Resilience in the context of EU CIRCLE is defined as the ability of a CI system to prevent, withstand, recover and adapt from the effects of climate hazards and climate change. Having conducted an extensive review of the literature on existing resilience frameworks, EU CIRCLE proposes a novel 4 layered approach to CI resilience: 1) Climatic hazard, climate change; 2) Critical infrastructure, their networks and interdependencies; 3) risks and impacts from climate change; and 4) capacity of critical infrastructure. The 4 layers in the EU-CIRCLE resilience framework which determine what constitutes critical infrastructure resilience and their key components are summarised briefly below:

1. Resilience of what – the context which is critical infrastructure, their networks and interdependencies as incorporated in Layer 1
2. Resilience for what – the disturbance which is climatic hazards, including current and future climate change represented in Layer 2
3. Risks and Impacts - which includes the consequences of a hazard and the likelihood of the occurrence, detailed in Layer 3
4. Capacities of critical infrastructure such as the ability to anticipate and reduce the impact; ability to buffer and bear; ability to be repaired easily and efficiently included in the final Layer 4
5. Resilience parameters i.e. properties that indicate different capacities are also included in Layer 4

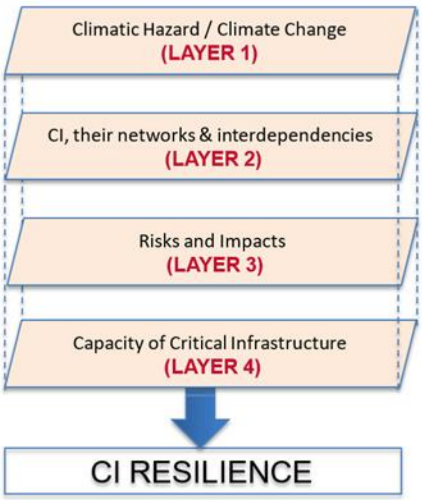


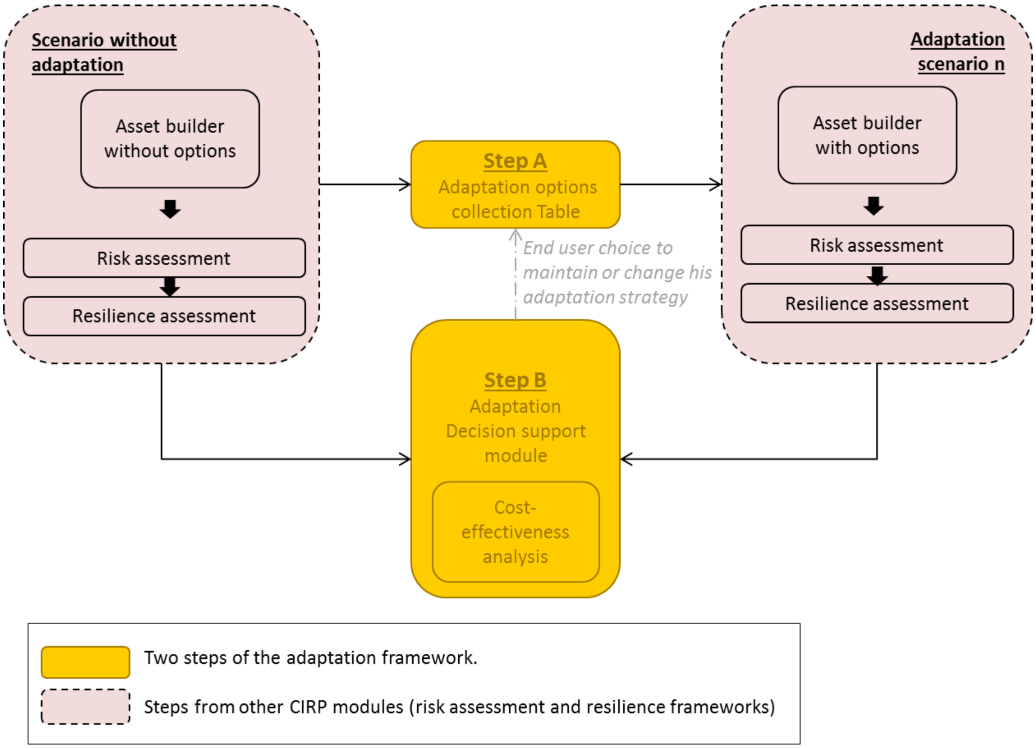
Figure 10. EU CIRCLE Resilience Framework

The EU-CIRCLE adaptation framework proposes a methodology allowing CI operators to identify, to assess and to select relevant adaptation options in order to improve their resilience to one or several climate change scenarios. This adaptation framework is consistent with the EU-CIRCLE risk and resilience assessment frameworks.

Description of the EU-CIRCLE adaptation framework

Build on a review of existing new approaches for decision-making under deep uncertainty (especially robust decision-making and adaptation pathways), this methodology is based on two main steps:

1. Step A: selection of a range of adaptation options, according to the risk and resilience analysis (scenario without adaptation).
2. Step B: assessment of the selected options, according to their impact on the resilience and to their cost-effectiveness (comparing both scenarios without and with adaptation).



These two steps are divided into seven concrete stages, as follow:

Step	Stage	Description
A/ Identification of adaptation options	1. Establishment of the decision context	Definition of the ***acceptable resilience level*** (CI operator point of view) within climate change context; using the EU-CIRCLE Resilience Assessment Tool.
	2. Identification of options	Identification of adaptation options to reduce the damages (assessed using the risk assessment framework) and to improve resilience capacities (assessed using the Resilience Assessment Tool).
B/ Adaptation Decision Support	3. Identification of objectives and criteria	Regarding the decision context, determination of criteria to evaluate the adaptation options (including

Module		resilience level & cost-effectiveness).
	4. Scoring of the expected performance in comparison to the defined criteria	Evaluation of the performance of each adaptation option against the selected criteria.
	5. Definition of weights for all criteria	Assignment of specific weight for each criterion with the decision makers.
	6. Computing the overall scoring/value for each adaptation option	Final analysis.
	7. Sensitivity analysis	Results analysis to assess their stability to changes in the input parameters (climate change scenarios, criteria weights, etc.).

4 EU-CIRCLE societal impact 3: localized impact & resilience assessment.

Five different real world Case Studies have been contacted during the project. The selected case studies have been designed to address climate hazards that are considered to be of high importance to the EU and cover all types of CI. ***The case studies were conducted, or more accurately, co-created with an impressive group of stakeholders*** that participated from the design to the evaluation of the case studies. The Table below describes the organizations that participated in each case study.

Table 3. Involved CI stakeholders per EU-CIRCLE case studies

Case Study	Involved CI operators, Local/Regional/National Authorities Non-project partners
CS1	RTE, ENEDIS, ESCOTA, Forestry National Organization
CS2	Electricity Authority Cyprus, VTT Vasilikos, Petrolina, Vasilikos Cement Plant, Cyprus Civil Defence, Department of Meteorology, Fire Department
CS3	South West Water, Western Power Distribution, British Telecommunication, Torbay Council (Highways, Emergency Planning, Engineering), Wales and West Environment Agency, Network Rail
CS4	Khulna Power Company, Centre for Environment and Geographic Information Sciences (CEGIS), Khulna City Corporation, Khulna University, Khulna University of Engineering and Technology, Khulna Water and Sewerage Authority, Khulna Development Authority, West Zone Power Distribution Company Limited, Bangladesh Meteorological Department
CS5	City of Dresden - Department of environment, City Sewage system operator, DREWAG, Dresdner Verkehrsbetriebe

The EU-CIRCLE resilience framework has been proposed as a versatile approach, that can be adapted and implemented at different levels, from the single CI asset, to the CI network and the network of networks within a city / region. In this process, the impacts to society and the environment are an integral part. The versatility of the framework has been demonstrated in the five case studies where localised hazard, impact assessments and resilience estimation have been provided. Since all case studies have been conducted with the enthusiastic participation of local stakeholders (not project partners) then the project is well positioned to have an impact on local society, since they are representing a real world situation.

4.1 Societal impact 3.1: Societal impacts from Case Study 1 "Forest Fire and Prolonged drought on French/Italian Borders"

The Case Study 1 conducted within the Provence-Alpes-Côte d'Azur (PACA) region. The case study focused on heat wave, dryness and forest fire impacts on three infrastructures: electricity transportation (operator: RTE) and distribution (operator: ENEDIS) networks and an highway (operator: ESCOTA).

Description of the region

The PACA region under consideration is an area of 31 400 km^2 with a population of 5 million inhabitants. It is located south-east of France and delineated south by the Mediterranean shore, north by the Alps, east by the Italian Boarder and west by the Rhone valley.

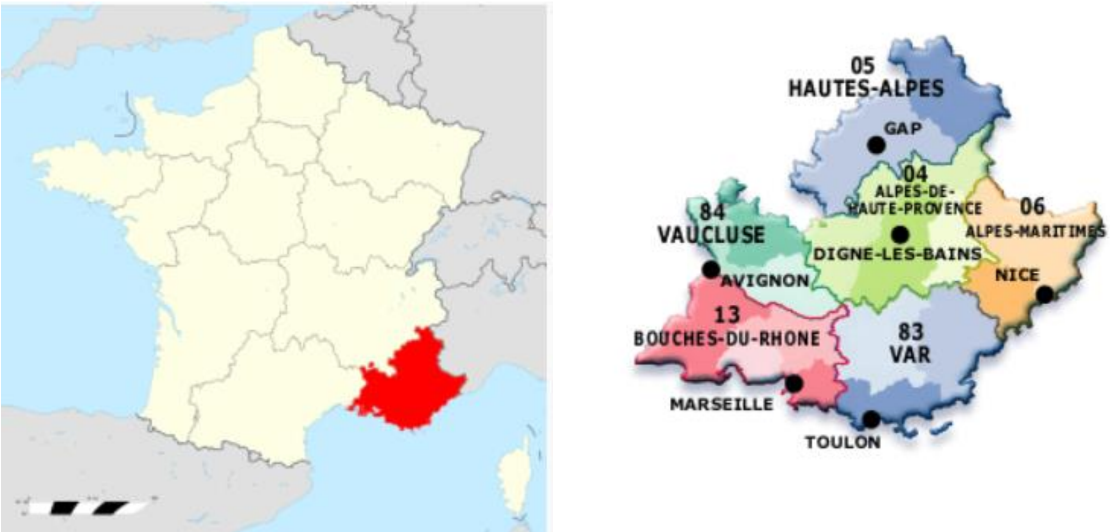


Figure 11. *Map of France and PACA region detail*

The case study focuses on the 3 "departments" (i.e. counties) located along the coast, from west to east:

- ✓ Bouches-du-Rhône (with the city of Marseille: 850 000 inhabitants - 2nd most populated city in France)
- ✓ Var (with the city of Toulon: 160 000 inhabitants, 15th most populated city in France)
- ✓ Alpes-Maritimes (with the city of Nice: 345 000 inhabitants - 5th most populated city in France)

<u>Demographics and tourism</u>

With 4.9 million inhabitants (2014), the Region is the third of the country in terms of population and appears as one of the most attractive regions (10% of the population has been living in the Region for less than five years). However, it is expected that the average age of the population (since one third of the population being over 60 years old). The population is not spread heavenly on the territory, 73% leaves less than 20 kms away from the sea shore.

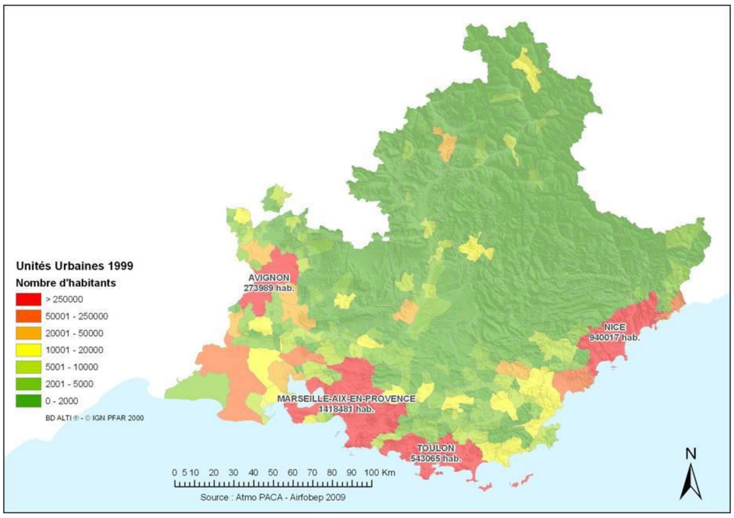


Figure 12. *Urban areas of PACA (Source: INSEE, 2007)*

Over 31 million tourists are hosted every year in the region. This region is the first destination for domestic tourism and 20% of the tourists are foreigners. Tourism represents 11% of the regional GDP and 120 000 jobs in the PACA region. Tourism is most important in spring and especially summer on the sea shore.

Economic activity

Provence-Alpes-Côte d'Azur Region is responsible for around 7% of the national growth. Tertiary activities and services (both public and private) account for 80% of the added value and paid employment. Industry ranks second representing 11% of the regional added value (figures from 2006). Since 2008, the economic crisis has had a particularly strong impact on the employment in the region. The unemployment rate indeed exceeds 11% (January 2017) while the national average is 9.7%.

The data indicate that, EU-CIRCLE could protect the lives, wellbeing and societal functioning of hundreds of thousands of people that could be exposed to forest risk. Furthermore, as is demonstrated in the Case Study, citizens located many kilometers from wildfires could be left without electricity and disruptions to transportation services occurring.

4.2 Societal impact 3.2: Societal impacts from Case Study 2 "Multi-hazard impact assessment at Vasiliko Energy Hub in Cyprus"

Case Study 2, focuses on multi-hazard climate change risk assessment and simulation of a low probability-high impact (HI-LP) event, and demonstrates the EU-CIRCLE risk management framework and the capabilities of CIRP.

Description of the Vasilikos area

The area considered in the case study is the greater Vasilikos Area located on the south coast of Cyprus, approximately 25 km east of the town of Limassol, 30 km southwest of the town of Larnaca and 40 km south of the island's capital city, Nicosia. The Vasilikos area is designated as a heavy duty industrial area and houses the island's largest power station (868 MW), two oil terminals, a port and the largest cement factory in Cyprus. The Government of the Republic of Cyprus plans to further develop the Vasilikos area into the island's primary energy hub, through the Vasilikos Energy Centre (VEC) project managed by the Department of Energy. The future VEC includes the creation and development of storage facilities for the Cyprus Organisation for Storage and Management of Oil Stocks (currently under construction) that will include the strategic fuel stocks for the Republic, a Liquid Natural Gas storage and regasification facility as well as petroleum products storage and truck loading facilities for the local market. The VEC is also the designated area for the relocation of petroleum storage facilities currently operating at Larnaca bay by 2019 and for gas storage facilities by 2020.

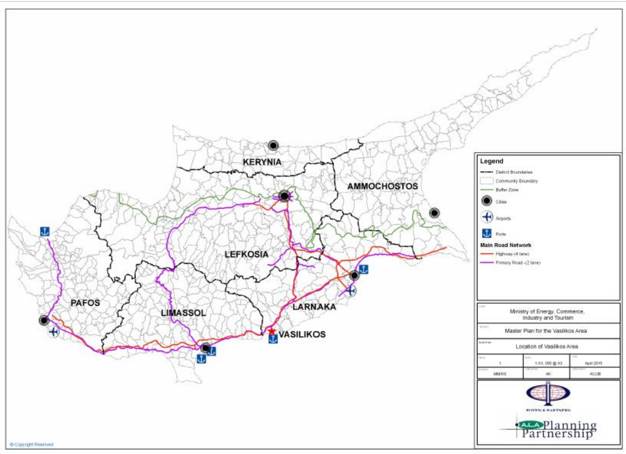


Figure 13. Map of Cyprus and Vasilikos

Demographics

The Vasilikos industrial area is classified as a Heavy Industrial Zone B2. The nearest residential development is Mari Village 1.7 km northwest of the site, which has a population of 158 people (2011, census) and the coastal community Zygi village with a population of 589 residents 2.5 km to the east.

Economic activity

The Vasilikos area is considered central to the energy industry of the island with several energy and industrial companies in the area. This strategic role will be enhanced as there are plans to build a 210,000 tonne privately-owned storage facility which will consist of six storage tanks for storing liquid fuels, pipelines and pumping states, fire and security systems, and an administration building. Furthermore, new energy infrastructure is planned in the area, including, amongst others, facilities for the import, storage and management of liquid fuels, LPG, asphalt, lubricants and related products. The Council of Ministers has also approved the development of the necessary infrastructure for the import of LNG in Cyprus, including a Floating Storage and Regasification Unit, a jetty intended for the Unit's safe mooring and, finally, the required pipelines, all to be installed at the Vasilikos area.

EU-CIRCLE co-created with different CI owners and operators a multi-hazard climate change risk assessment framework to assess their resilience in future climate. The case study showed that oil facilities are well protected against most climate threats and decided that further cooperation would be beneficial for the resilience of future investments.

4.3 Societal impact 3.3: Societal impacts from Case Study 3 "Flooding in the UK"

CaseStudy 3 is focused on the effects of coastal flooding on critical infrastructure (CI) within Torbay. This CS will test the framework for assessing the impacts on the CI around Torbay as a result of coastal flooding under the present and the future climate change scenarios. The assessment includes the damage to residential and commercial properties, together with the impact of flooding to highways, transportation, tourism, local economy, infrastructure (sewers, gas, electricity, water, telephones, etc.), health and the local environment.

Description of the region

Torbay is located in South Devon (UK), as shown below, and has an area of approximately 62km2. Torbay has an extensive coastline extending from the boundary with Teignbridge to the boundary with South Hams. It is on the south west coast between the main cities of Exeter and Plymouth. As Torbay has developed over the years it has become one of the main tourist resorts within England and is known as the English Riviera. Much of the catchment area is urban comprising three main towns of Torquay, Paignton and Brixham. Torbay Council is a Unitary Authority which covers the towns of Torquay, Paignton and Brixham in the UK, as shown in Figure 14. *Location of Torbay and administrative borders*. It delivers over 700 services to more than 130,000 residents and the many visitors who come to the Bay every year.

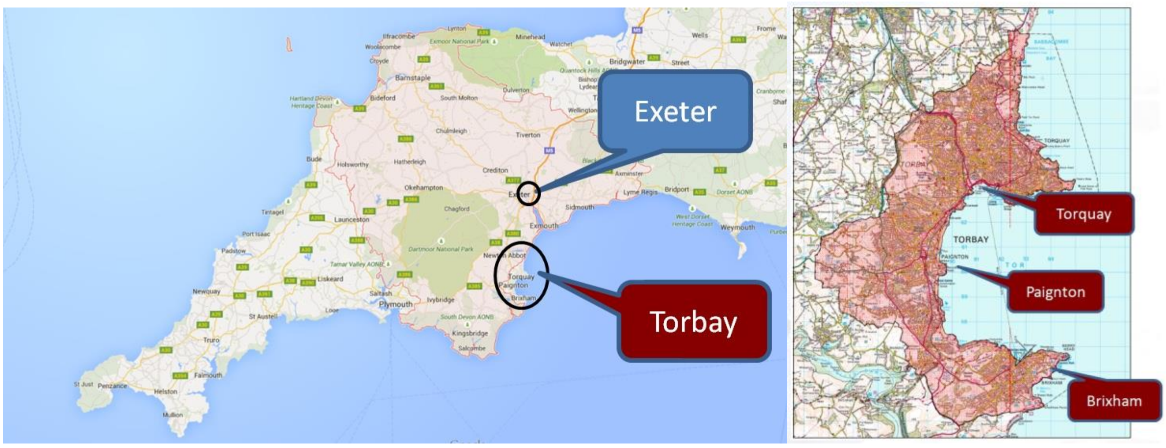


Figure 14. *Location of Torbay and administrative borders*

Demographics and tourism

Torbay covers an area of approximately 62 km2 as a popular tourist destination in the UK. The region includes three urban towns (Torquay, Paignton and Brixham) and hosts more than 3 million tourists every year that contribute over £450 million to local economy.

Economic activity

The principle economic activities are tourism and fishing. Torbay has a large amount of holiday accommodation and tourist attractions. At the peak of the summer season the population of Torbay doubles due to the number of tourists visiting the region. Brixham is a historic fishing port that today lands the highest value of catch of any fishing port in England and Wales. In the current year the total value of the fish sold at Brixham Fish Market is estimated to be £40.4 million.

EU-CIRCLE has been used by Torbay City Council to support the application for funding of coastal defences, that having a direct policy impact. These defensive measures are expected to further strengthen the resilience of the coastal cities and protect a growing population.

4.4 Societal impact 3.4: Societal impacts from Case Study 4 “Major cyclone in Khulna Bangladesh”

Case Study 4 focused on the Khulna City region of Bangladesh. The Khulna case study highlights the cyclones and storm surges impacts on the critical infrastructures of communications, water, power, transport and buildings.

Description of the region

The Khulna area in Bangladesh is a significant interior coastal city situated roughly equidistant between the C40 megacities of Dhaka Bangladesh and Kolkata, India. The city of Khulna is the second port city of Bangladesh and the third largest in size. Approximately 100 km from the coast and just north of Mongla Export Processing Zone and port complex and the under construction Rampal coal power station and Khan Jahan Airport, Khulna is a growing regional hub with a dense historic experience of tropical cyclones a persistent urban drainage problem and a projected storm surge risk.

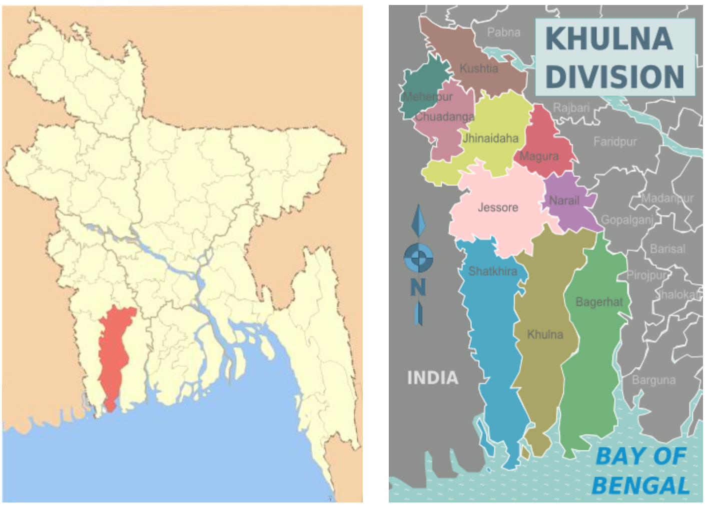


Figure 15: Map of Bangladesh and the Khulna division

Demographics and tourism

With a population of 1.4 million projected to reach 2.9 million by 2030 (UN-DESA, 2012), it is a site of current infrastructural development, rural to urban migration, and a strategic refuge for environmental refugees responding to impacts of upstream water withdrawal, extreme weather events and climate change. Overall, 46% of the land area of Khulna is residential, 18% is farming land, 15% is industrialized areas and 5% is commercial areas, while the rest consists of official structures, transport infrastructure, community and defence, facility parks and water bodies (Institute of Water Modelling, 2010).

Economic activity

The wider industrial economy around Khulna is also important to consider, alongside the observation that a lot of new infrastructure is presently being assembled. Established in 1950 the Mongla port, 60 km inland, served the regional import export economy until challenges like the jute price decline of the 1980s triggered closures of local mills and reorientation of exports towards sectors like Ready Made Garments. The underdevelopment of the port facilities and river navigability is presently being addressed by significant central government investment. Along with the construction of a local airport and the Rampal power plant, the reopening of the Khulna-Kolkata rail connection, and the opening up to tourism this suggests a positive economic, if not ecological and social, trajectory for the region and its Export Processing Zone.

Khulna city is the 3rd Industrial city of Bangladesh currently living the revival with growing infrastructure projects. Under climate change, an increasing cyclone vulnerability is projected. EU-CIRCLE could provide a useful tool for protecting Khulna and preventing from turning into a future Climate Refugee-city.

4.5 Societal impact 3.5: Societal impacts from Case Study 5

The case study area (Figure 16) is located in the eastern part of the city between the bridge „Blaues Wunder“ and Pillnitz. The population is around 35 000. There are mostly residential buildings and some smaller public buildings, such as schools and retirement homes. Close to the river is a state road with around 10 000 cars daily that connects the city of Dresden with neighbouring towns and villages (i.e. Pirna). If the road is blocked due to inundation, long detour is required. The area close to the river has been flooded in previous floods 2002 and 2013 and that lead to: huge efforts for evacuation, road traffic disruptions for individual cars but also for public transport, power cuts, and service disruption in sewage system.

Dresden has suffered from flooding in the past. The most notable events include:

In August 2002, extreme torrential rain lead to rapidly rising water levels in the Elbe catchment area in the Czcech Republic and the Ore Mountains. the Elbe reached a peak of 9.40 m on August 17. In the Free State of Saxony, the 2002 flood caused 21 fatalities. About 35,000 people had to be evacuated solely in Dresden. About 280 social facilities (such as hospitals) were affected. Estimations for the total damage costs amounted to 8.6 Billion EUR, since 540 km of road and more than 25,000 buildings were damaged. The flood also impacted the historic center of Dresden.

In April 2006, Elbe reached a level of 7.49 m in the city centre of. Minor areas in the southeast of Dresden were inundated. Hence, the total damage was small and traffic disruptions came to a few incidents.

In June 2013, Elbe gauge reached 8.78 m, and the flood was classified as HQ 50 to HQ 100 event. About 6% of the city area was declared as distressed area which affected about 52 000 people. Since the city of Dresden adopted flood protection measures in advance and improved flood protection management, the total damage of the 2013 flood was much lower than in 2002.

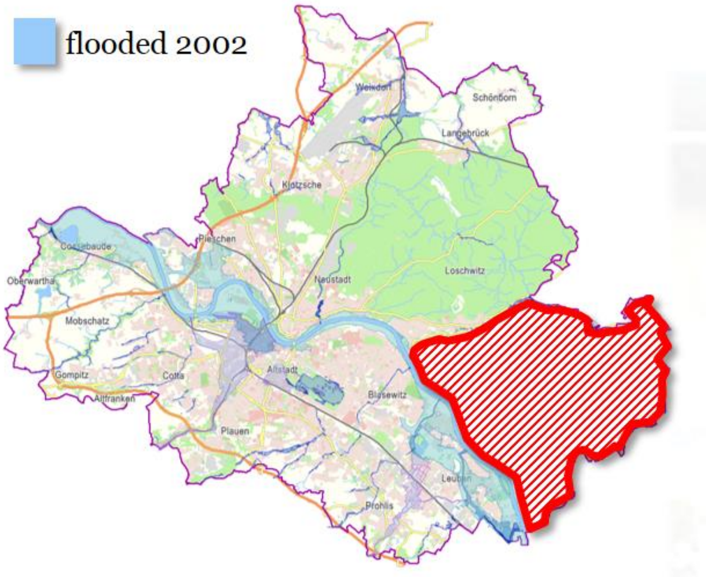


Figure 16: Case study location in Dresden/Germany.

Source: Themenstadtplan Dresden[3] (Landeshauptstadt Dresden, 2018a)

The use of the EU-CIRCLE on Dresden, revealed some previously unaccounted for interconnections between the sewage network and

[3] http://stadtplan2.dresden.de/(S(ap4qgiga10xbrsw3ueaesons))/spdd.aspx?TH=STA_VERKEHRSMENGEN&POS-LatLon=51.049156%7C13 (access date 27.09.2018)

5 EU-CIRCLE societal impact 4: Awareness raising activities

EU-CIRCLE, from its conception placed high importance on awareness raising activities. To this extend a multi-dimensional set of activities have been designed and implemented. The project partners have been engaged in multiple activities targeting diverse audiences that include the CI community (owners and operators), Critical Infrastructures Authorities and Civil Protection Agencies at different governmental levels (National, Regional and Local) and members of the climatology and meteorology community. The project partners have been engaged in multiple exchange of knowledge and discussions with similar funded projects both from the EU and internationally, during specifically organised events, scientific conferences and infodays. EU-CIRCLE showed a strong presence in the web and related social media though constantly publicizing the generated knowledge and results to the widest possible audience.

5.1 Societal impact 4.1: Impact of dissemination activities

Dissemination actions, are extensively described in D8.5 and D8.6 for the two project periods respectively. Overall, the project achieved dissemination targets set in the DoA. EU-CIRCLE reached the KPIs targeted during the first period of the project, as shown in Figure 17.

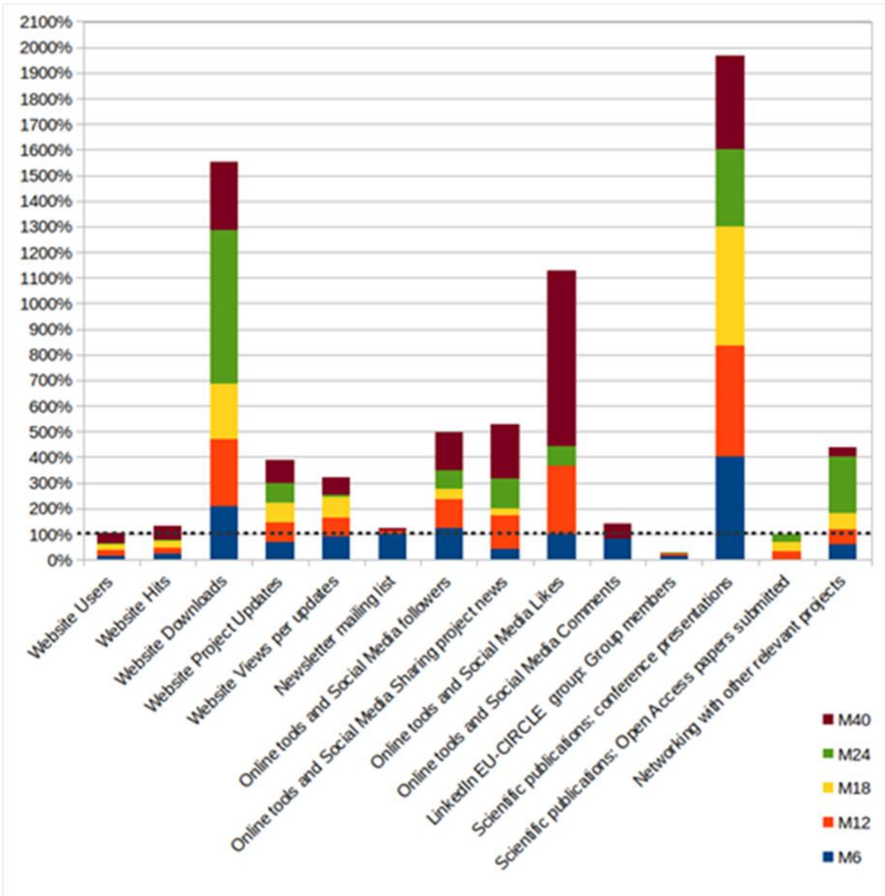


Figure 17 EU-CIRCLE achieved KPI’s M1-M40

In summary the main achieved impacts from dissemination activities summarised from D8.6 include

O1. Raise awareness of the project’s aims and subsequent results at the local, national, European and international levels, through more than 150 different activities

O2. Increase the reputation and visibility of the project and its constituent partners, as for example electronic dissemination media reached more than 5000 persons and the collective number of participants in related events reached cumulatively the order of a few hundreds.

O3. Promote the project's results to CI stakeholders through the establishment of a bi-directional communication channel with them.

O4. Promote and generate demand for CIRP and other project results to the CI and other relevant stakeholder communities.

O5. Seek industrial partners from the CI community for testing and capitalising the project's results , through the project's exploitation model available at http://www.dappolonia-innovation.com/eu_circle/

O6. Align the project's dissemination activities with calendar events of relevant EU programmes & other initiatives, through the participation in CDB, ECCA 2017 joint session

O7. Share know-how and project outcomes with the relevant scientific communities, as indicated by the participation in 46 events.

O9. Overall, depending on the type of audience reached during the dissemination activities the number reached the thousands (section 5.5)

5.2 Societal impact 4.2: Training material

D8.8 presents the training material of EU-CIRCLE. The Training material is prepared that will allow the project partners and the community to gain insights and promote the implementation of CI climate resilience to stakeholders and educate the next generations, especially give the worldwide trend to establish "resilience engineering" courses. It is a self-paced course addressed to professionals, academics, researchers and others (authorities, institutions etc.) involved or interested in critical infrastructures, climate change and resilience.

The training material builds around a pedagogical model (e.g. who is the training addressed to, what are the objectives of the training, what are the key outcomes etc.?) and an online platform which hosts the e-training[4]. The key material that has been produced during the project's duration includes:

Module 1: Introduction to Climate Change Science

Module 2: Climatic Data Capture and Processing

Module 3: CI impacts to climate change

Module 4: Holistic CI Climate Hazard Risk Assessment Framework

Module 5: EU-CIRCLE Resilience Framework

Module 6: Adapting Critical Infrastructures to Climate Change

5.3 Societal impact 4.3: participation at EU events and synergies with other projects

EU-CIRCLE participated in four events that were under the auspices of the EU and established synergies with numerous projects (e.g. Common Dissemination Booster) and international initiatives.

DRMKC – Brussels.EU-CIRCLE (NCSRD and UNEXE) participated in the DRMKC event held on 16-17th March 2017 at Belraymont building in Brussels.

Community of Users – May 2017. EU-CIRCLE participated in the workshop on Climate Clustering during the 7th CoU.

Community of Users – June 2018. During the 11th CoU meeting, EU-CIRCLE participated at the Thematic Workshop – Theme 9: Extreme Weather and Climate Events - Afternoon session. Dave Stewart from TORBAY presented the project's 3rd Case Study and University of Exeter and Satways provided live demonstrations of CADDIES and CIRP.

[4] https://eu-circle.coders-lab.eu/

The participation of EU-CIRCLE in Common Dissemination Booster has been performed for three services jointly selected with other DRS9 projects, under the “CDB-3 RESCCUE”.

5.4 Societal impact 4.4: EU-CIRCLE workshops

During the project duration EU-CIRCLE organised two large workshops with the extensive participation of stakeholders. They are described below:

5.4.1 Consolidation Workshop

In May 2016 the Consolidation Workshop organized by Project Partner DAPPOLONIA in Milan. Main objectives of the workshop were about to strengthen the interaction among the stakeholders dealing with Critical Infrastructures and climate change, validate the framework of the project in its initial stages and discuss how the case studies could be conducted. Details of this workshop are presented in D1.6

Figure 18. (L) Participants in the Consolidation Workshop ; (C)Presentations for “The typhoon Nari in 2001” by the National Taiwan University; (R)the “The Netherlands approach for Critical Infrastructure Protection” by Jeroen Mutsaers, CIP.

5.4.2 Final Workshop

The EU-CIRCLE final workshop has been conducted in the premises of Fraunhofer IVI at Dresden, Free State of Saxony on August 29, 2018. The workshop has been conducted in parallel as the main dissemination event of the project’s “Case Study 5: Rapid Winter Flooding around Dresden, Germany”, which gave the opportunity to invited guests and participants to get a deeper understanding on the EU-CIRCLE achievements over its course. The Workshop is described analytically in D8.6 and D6.11.

Figure 19. EU-CRICLE Final Project Workshop group photo

5.5 Summary: number of people reached by category

During the EU-CIRCLE, a great effort was made to diffuse the knowledge and experience gained to different groups of people. A large amount of activities (a total of 156 – D8.6 Figure 13), were made by project partners, with the most "popular" type of dissemination action was the participation to conferences alongside the pitch events and workshop organisation. According to collected data, Figure 20, the scientific community and general public hold the majority of people reached, indicating an effort (a) to peer review the methodology used and create a feedback loop in order to create a more robust result, and (b) to announce the goals and scope of the project to the general public in a comprehensive way.

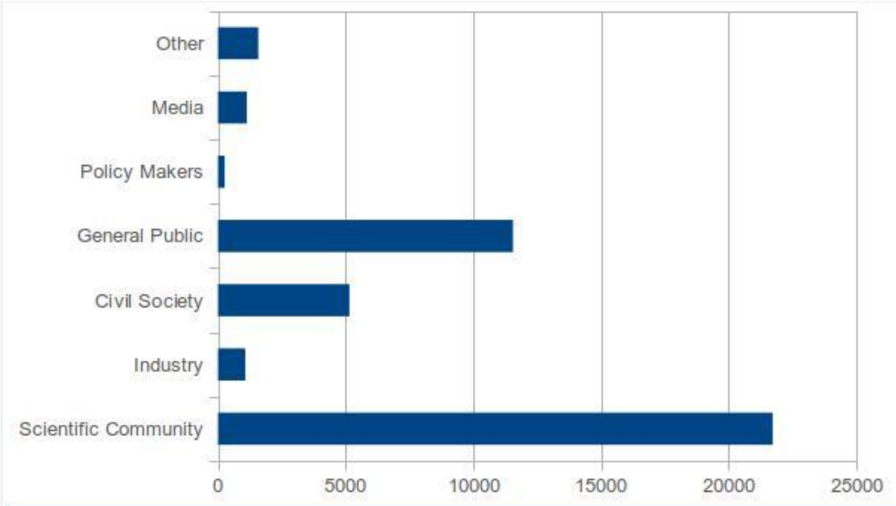


Figure 20: Type of groups reached versus amount of people

5.6 Gender dimension

The consortium fully respected the gender balancing principle as described in the DoA. Overall the number of female researchers that participate in the project is approximately 40% of the total participants. Furthermore during the recruitment process, none of the project participants include any selection criteria that are discriminatory towards gender.

Concerning the participants in dissemination events there couldn't be made a precise estimation, but in conferences, workshops and other face to face dissemination events the distribution was similar to the scientific domain.

6 EU-CIRCLE societal impact 5: Contribution to innovation growth

The project, although a Research and Innovation Action, made consolidated efforts to contribute to competiveness and innovation growth.

6.1 Societal impact 5.1: EU-CIRCLE exploitation model

EU-CIRCLE established and implemented a unique exploitation model (final version presented in Deliverable D8.13) that projects tools, data and solutions could be presented to potential customers. Through use of the commercial portal, interested parties will be able to search for available products and services or to express specific needs that other users could provide if interested. In this way a market on CI resilience services, data and tools can grow, creating a network of collaborating stakeholders and spreading the use of the EU-CIRCLE project results for application in world-wide real-life cases. Under the proposed scheme, , tools and resource items can be offered with different licensing type ranged from open data and open source paradigms, to closed source/not redistributable but free of charge licensing, to commercial selling or usage fees (per application, per year, per number of users, etc…). The platform - l portal itself is accessible on the web at the address "http://www.dappolonia-innovation.com/eu_circle/" and its usage is described in D8.10 & D8.13.

6.2 Societal impact 5.2: EU-CIRCLE developed tools and data

EU-CIRCLE Proposed, developed and tested a series of tools that account for the multi-dimensionality of CI climate change resilience. These include the Critical Infrastructure Resilience Platform (CIRP), the Resilience Assessment Tool (RAT), hazard simulation and visualization tools. Also the virtual data set (Deliverable D7.4) with CI data and reference hazards has been made available to the stakeholder and academic community. The main tools developed within the project are:

CIRP constitutes an innovative modular and expandable software platform that will assess potential impacts due to climate hazards. CIRP offers as an end-to-end collaborative modelling environment where new analyses can be added anywhere along the analysis workflow and where multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner providing an efficient solution that integrates existing modelling tools and data into a holistic resilience model in a standardised fashion.

RAT is a tool to measure resilience, organised on different hierarchy levels (D4.5): Highest level is the overall resilience index as a composite or aggregate indicator depicting the level of achievement in the five aspects related to resilience capacities: anticipation, adaptation, restoration, coping and absorption.

6.3 Societal impact 5.3: Contribution to climate services

EU-CIRCLE created multiple climate data and hazard simulations in support to the case studies. These have been gradually and will continue in the coming period to be made available to the community through the climate services initiative.

Furthermore, virtual datasets were created base on a reference region. The datasets are related to Critical Infrastructure data, Forest Fire and Flood Hazards and a number of supplementary data for supporting the Hazard and Risk modelling procedures. They were made available at doi: 10.5281/zenodo.1408743

6.4 Societal impact 5.4: Contribution to standards

Finally, EU-CIRCLE attempted to establish metadata standards in support of orchestrating the different and diverse models that were used. A complete metadata standards suite has been used from climate and hazards (D2.4) to CI description and risk assessment (D3.6) and resilience (D4.8). Collectively these have been presented in D8.11 and have been submitted for consideration to Open Geospatial Consortium - OGC.

7 References

Croce P., Paolo Formichi, Filippo Landi, Paola Mercogliano, Edoardo Bucchignani, Alessandro Dosio, Silvia Dimova, The snow load in Europe and the climate change, Climate Risk Management, 20, pp. 138-154, 2018.

EEA Report No 1/2018 National climate change vulnerability and risk assessments in Europe, 2018, ISBN 978-92-9213-940-7

ESPON, Climate change and Europe's regions [https://www.espon.eu/topics-policy/publications/maps-month/climate-change-and-europe%E2%80%99s-regions]

Forzieri G., Alessandro Cescatti, Filipe Batista e Silva, Luc Feyen, Increasing risk over time of weather-related hazards to the European population: a data-driven prognostic study, The Lancet Planetary Health, Volume 1, Issue 5, Pages e200-e208, 2017,

Forzieri G., Alessandra Bianchi, Filipe Batista e Silva, Mario A. Marin Herrera, Antoine Leblois, Carlo Lavalle, Jeroen C.J.H. Aerts, Luc Feyen, Escalating impacts of climate extremes on critical infrastructures in Europe, Global Environmental Change, Volume 48, Pages 97-107, 2018.

JRC Technical Report Resilience of large investments and critical infrastructures in Europe to climate change, Final report for DG CLIMA, 2015, ISBN 978-92-79-54003-5

Rogers Gibson J., 2017, Built to Last, Challenges and Opportunities for Climate-Smart Infrastructure in California [https://www.ucsusa.org/global-warming/regional-information/california-and-western-states/climate-smart-infrastructure#.W8mZhXszaM8]

SWD(2017) 176 final, Overview of Natural and Man-made Disaster Risks the European Union may face, Brussels, 23.5.2017