EU-CIRCLE

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

D1.5 Report On Detailed Methodological Framework - Final Version

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Statement

EU-CIRCLE D1.5 presents the application of the methodological framework derived in D1.4 and validated in the Milan Consolidation Workshop (May 2016), as will be applied in the Case Studies of the project.

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Executive Summary

The methodological framework, which is defined in D1.4 is further elaborated in this document, based on the input from several contacts with the stakeholder groups and the pilot case owners during the EU-CIRCLE Consolidated workshop in Milan. The methodological framework of the project is here adapted to the context of the pilot cases that EU-CIRCLE will use to test and validate its R&D results. Furthermore several operational and policy questions, associated to the potential use of the project tools to address issues and strengthen the resilience of the critical infrastructures against eventual climate change aspects are considered. The main objective of this documents is to highlight how the methodological framework shall integrate the project results in order to contribute or support the resilience and strengthen the protection of CI against climate change impacts.

The EU-CIRCLE shall provide a number of tools and methods which may improve the adaptive response and resilience of critical infrastructures against projected climate change. The purpose of this report is to build on the methodological framework defined in D1.4 and the case studies of EU-CIRCLE in order to examine a variety of options that may contribute to the protection and resilience of infrastructures, elaborate relative approaches for assessing risks and revise resilience potential and to determine operational and policy questions that the project could address.

The methodological framework of D1.4 and the context of using it together with the tools that EU-CIRCLE, as described in this document and based on the respective case studies, aims to deliver will support the related stakeholders to elaborate design, planning and retrofitting suggestions and if possible consider revision proposals on existing standards (CEN-CENELEC Guide 4 'Guide for the inclusion of environmental aspects in product standards' and Guide 32 - 'Guide for addressing climate change adaptation in standards', Eurocodes etc.), towards climate-proof and resilient infrastructures.

Contents

1 Introduction

This deliverable report (D1.5) is based on the EU-CIRCLE methodological framework, which is defined in D1.4, applied in the context of the study cases that have been determined by the project for testing and elaborating the EU-CIRCLE findings and results. Furthermore it includes the feedback relative to the project approach and proposed methodology, which was gathered by stakeholders, in context of several meetings and in particular linked with the discussions during the Consolidated Workshop that was held in Milan the 18th of May 2016.

During the workshop stakeholders, representing the study cases of the project, provided their experience and expertise and evaluated the proposed EU-CIRCLE approach regarding risk assessment and resilience strengthening and they have enlighten several aspects that are further considered and presented in this deliverable. The consortium had several debates and exchanged a number of relevant ideas with representatives of stakeholder groups in a series of meetings, which are culminated with the Milan Workshop. These meetings initiated a process of reflection on:

- the EU-CIRCLE conceptual approach
- the eventual foresight analysis options
- the risk assessment methodology adopted
- the aspects of the methodological approach
- the scenario building context
- the challenges of assessing the impact to CIs (direct, due to interdependencies and cascading effects)
- the options of resilience strengthening in the envisaged infrastructures
- the CI and environmental settings of the areas of the study cases

Thus, past cases of climate hazardous events and their impact to CIs were used to support discussion and analysis while information and data needed for preparing the study cases of EU-CIRCLE were determined. Feedback regarding the familiarization of the CI owners and operators with climate-change related hazards and threats in order to include these aspects in the formal Business Continuity (BCP) and Operating Security Plans (OSP) of their organizations was gathered, discussed and analyzed based on relative questionnaires filled by stakeholders. Relative conclusions included in D1.4.

EU-CIRCLE has developed a concrete methodological framework aiming to define ways that a multi-disciplinary and inter-organizational group of relevant stakeholders might cooperate to perceive and assess the impact of climate-change potential. The expected result from such synergy would be the development of adequate and proper adaptation measures, which can ensure operational, societal, environmental and economic resilience against eventual climate changes. The envisaged framework has to support numerous business decisions while complying to specific policy objectives and considering relevant scientific hypotheses. The methodological framework proposed aims to ensure the coordinated collaboration and synergy among the EU-CIRCLE stakeholders, comprising national or regional authorities, physical security experts and critical infrastructure operators as well as researchers from the climate change and the hazard modelling communities in order to plan for strengthening the resilience of infrastructures against climate change impacts. Representative decisions that may detain the aforementioned stakeholders group could include the following:

• Increase the magnitude of design parameters or safety factors

• Perform formal risk assessment and carry out climate change risk management

• Review existing practices and consider new design and planning solutions

• Develop contingency plans for infrastructure failure

• Identify infrastructure that is at risk because of a changing climate and retrofit priority assets

• Consider increased deterioration rates in design and maintenance plans

• Consider different climate change scenarios or models for design, maintenance or planning

• Identify locations that may be vulnerable to climate change impacts and avoid them altogether or modify designs accordingly

The EU-CIRCLE framework suggests a consistent and cooperative process allowing to address challenges and support decisions, starting from adequate climate change scenarios, moving to relative risk assessment and coming up with resilience metrics that may indicate countermeasures and adaptation plans required for improving the protection level of the envisaged CIs. This process is depicted in Figure 1.

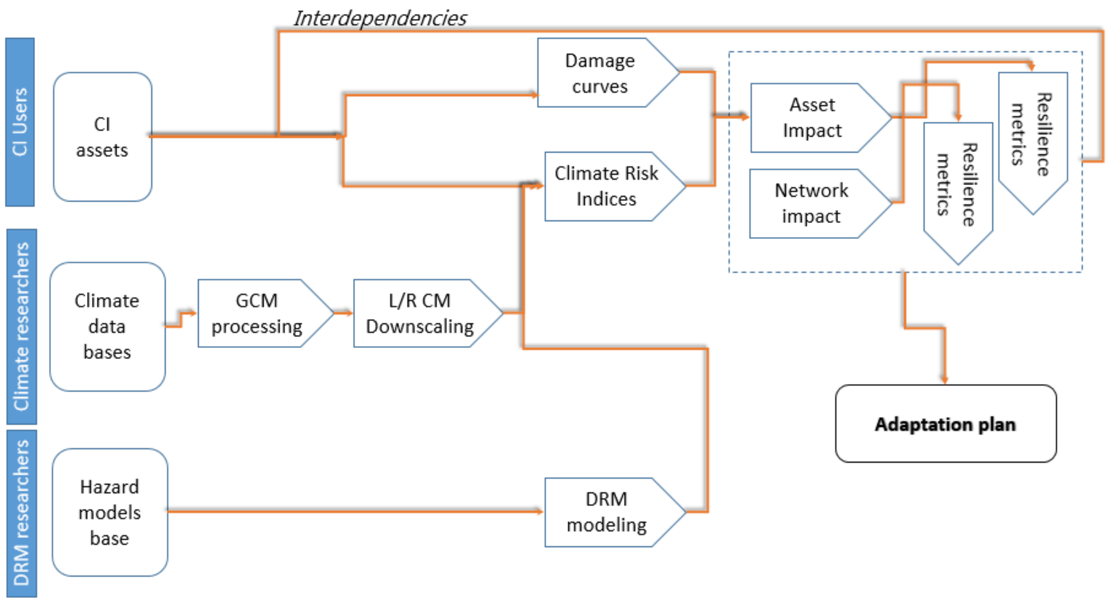

Figure 1. Cooperative process of implementing the methodological framework of EU-CIRCLE

EU-CIRCLE project focuses to support national authorities to improve the preparedness of the Member states of the European Union to address climate-change related events and minimize the relative extent of economic loss and societal disruption. The EU-CIRCLE results aim to (1) contribute to the capability of the authorities and CI managers to predict and detect climate-change driven events which may have impact to the integrity and performance of infrastructures providing essential services and their key assets, (2) establish a relevant context and define procedures and activities that will alert the CI owners and operators to enable mitigating actions for addressing climate change impacts (3) organize and coordinate the development of protection and adaptation plans, elaborate mitigation measures and protocols, and adopt proper standards that are required to reduce risks and ensure outstanding resilience performance of a critical infrastructure prior to and during a climate-change driven credible threat, and (4) provide the ability to respond to and recover from the eventual consequences of climate change.

The EU-CIRCLE methodological framework allows all stakeholders to cooperate in context of well-defined procedures as shown in the next figure (Fig.2).

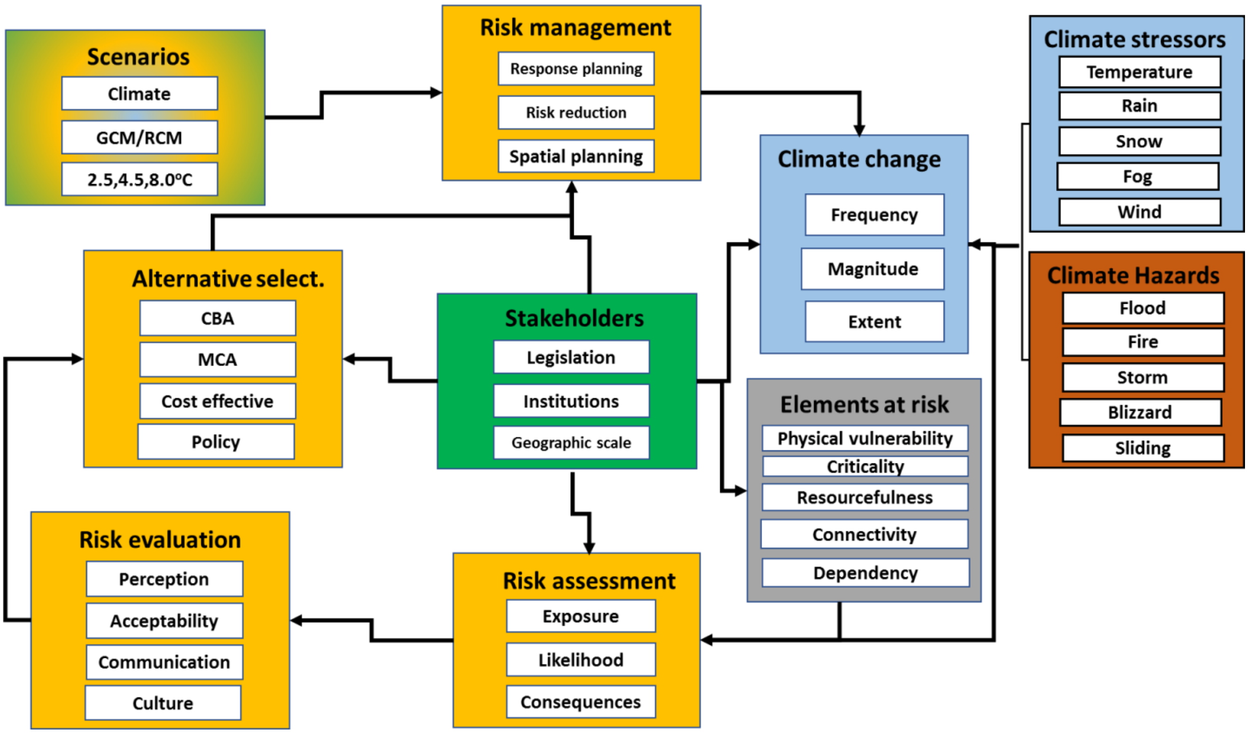

Figure 2. Detailed framework of the EU-CIRCLE procedures showing the stakeholders involvement (brown:hazard modelers, blue:climatologists, green:public stakeholders, yellow:risk modelers, purple: CI operators)

Among the project stakeholders, the public services and national authorities will be benefit by using EU-CIRCLE results to coordinate their efforts to be prepared to address the effects that the global change may have on critical infrastructures and relative services. In addition the critical infrastructure managers and operators can be supported to perceive timely latent issues and to back eventual investments needed to preserve the performance and reputation of their service.

2 Deliverable scope and objectives

The present document is formally considered as the Final version of the deliverable D1.4 (Report on Detailed Methodological Framework - initial version). The relation between these two deliverables (D1.4 and D1.5) is that D1.4 presents the details of the EU-CIRCLE Methodological Framework while the present document focuses on how this methodology could be used based on the planned project results and technical output. The D1.5 includes the final conclusions concerning the use of the methodological framework by potential end users and presents use cases of EU-CIRCLE implementation, based on the DoA description, the particular study cases that are considered in context of the project and the feedback received by the stakeholders contacted during the first year of the project and those who participated in the Milan workshop of EU-CIRCLE.

The document integrates information gathered and feedback received from the owners of the case studies envisaged by the project and highlights issues that are or may be considered in context of the exercises planned for the evaluation of the performed R&D. This could help the end users that will be involved in the project study cases to be familiarized with the potential use of EU-CIRCLE to support their planning and management tasks and to help them to be prepared to shape-up the methodological framework of EU-CIRCLE and perform efficiently its validation during the planned trials and proof of concept events. Therefore the description of the project issues in this document are rather seen from the end user point of view.

The project study cases are briefly summarized in this report and issues related to their adaptation to the conceptual and methodological framework of the EU-CIRCLE are presented in order to be considered during the implementation of the respective table top exercises and demos (trials). However, it has to be clear that this document isn't a report on the planning and preparation of the case studies of the project. It aims only to feed the planning process of the respective demos and related exercises with the organizational context that refers to the EU-CIRCLE methodological framework as well as with examples and potential options for using the Climate Infrastructure Resilience Platform (CIRP) in context of the planned trials from the end user viewpoint. In addition, this deliverable provides some policy and management related options concerning the proof of concept of EU-CIRCLE, in frame of the planned exercises.

It has to be noticed that this report, together with D1.4, can be considered as support documents for perceiving and understanding the requirements of end users that will use the EU-CIRCLE outcome and the CIRP tools for supporting resilience related decisions. The document provides a concrete methodology that the users can follow to define key assets protection priorities, assess potential risks, identify and validate resilience options and elaborate eventual adaptation measures that may strengthen resilience and improve protection.

The following chapters of this document provide a variety of aspects linking the EU-CIRCLE methodological framework described in D1.4 with the Climate Infrastructure Resilience Platform (CIRP) tools through the project study cases mentioned in the DoA. More specifically Chapter 3 presents the way that the methodological framework can be implemented using the CIRP. Chapter 4 briefly introduces the risks and consequences of climate-driven threats and hazards to CIs, associated with the specific project study cases. References to past events and risks relevant to those considered in the study cases that are considered in the project trials are provided in Chapter 5, while challenges to critical infrastructure protection and lessons learned from relevant past events are included in Chapter 6. The Chapter 7 provides ideas and suggestions to be considered when using in the future the EU-CIRCLE methodological framework and the CIRP tools. The most concrete ideas that can be considered within the context of the project and which may allow validating the use of EU-CIRCLE capabilities as well as the appreciation of the project's methodological and informatics tools, based on their potential use for the envisaged case studies, are included in Chapter 8.

3 EU-CIRCLE framework and tools implementation

EU-CIRCLE aim is to provide the stakeholders of CI resilience with a methodological framework, which is described in D1.4, for assessing risk and addressing potential impact of climate-related threats and hazards to the operation and resilience of National Critical Infrastructures. This methodological framework will be supported by the Climate Infrastructure Resilience Platform (CIRP) which is developed by EU-CIRCLE. CIRP provides a shared modelling environment where multiple scientific disciplines can work together with CI operators and relevant National Authorities in order to identify climate and climate-change related stressors to CIs, define their relation and influence to isolated or interconnected assets of critical infrastructures, understand interdependencies among CI networks, evaluate alternative adaptation solutions and present findings in a unified manner. The platform aims to assess potential impacts to CIs due to climate hazards, provide monitoring through resilience indicators and support cost-efficient adaptation measures.

According to D1.4 the steps of the EU-CIRCLE methodological framework include: (a) Scenario selection, (b) Scenario elaboration, (c) Data collection, (d) Scenario execution and on the spot analysis, (e) Assessment of results and policy suggestions.

Different methods (Fig.3) comprising brainstorming [2], scenario building [3,4], general morphological analysis [5] and future wheel [6] are comprised in the EU-CIRCLE methodological approach for implementing these consecutive methodological steps.

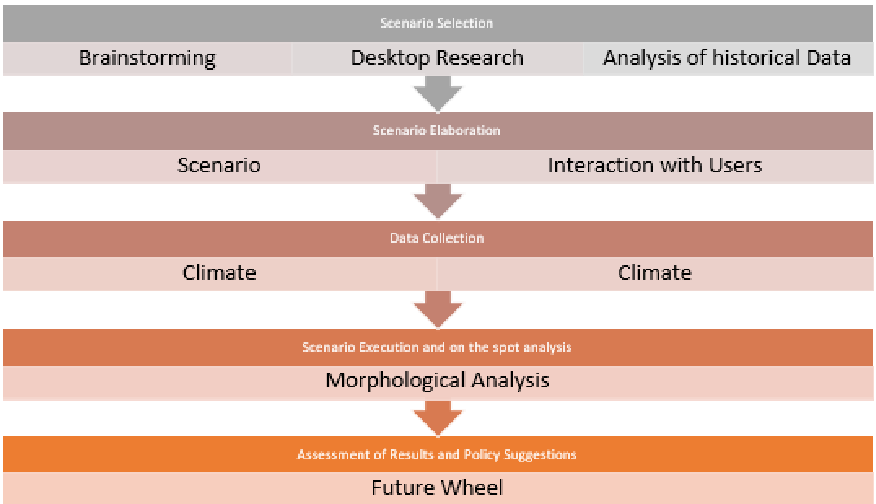

Figure 3. Flow process model of the EU-CIRCLE foresight analysis

The methodological process of EU-CIRCLE is proposed to be organized following the next procedural steps [7]:

1. Define the settings i.e. Area of interest, time period, CI types & network by CI community
2. Identify CC drivers to CI challenges and climate hazard precursors (use EU-CIRCLE results)
3. Compare climate related engineering design standards (e.g. return period) in place with relevant EU-CIRCLE CC assessments (by CC and DRM in cooperation)

4. Use CC modelling and project climate data to identify risk periods of climate change scenarios per CI type by the CC community (based on EU-CIRCLE defined scenarios)
5. For each risk period use CC modelling and project climate data to Identify risk areas of climate change scenarios for all CI types by the CC community (based on EU-CIRCLE defined scenarios)
6. Run disaster management spatial modelling
7. Identify and define damage/consequence curve per CI element (sector, service and/or asset)
8. Identify and define resilient indicators per CI element (downtime, minimum performance level, time to complete recovery, cost of repair ..)
9. Adapt all information in the EU-CIRCLE risk assessment framework
10. Run CIRP to define for each use case (incl. settings, CC model, time period and area of influence)
    a. Which CI elements are at risk to fail (resilient vs non resilient) as individual assets, interconnected units (network or service) or interdependent services (cascading effects)
    b. What will be the expected impact (population, cost, environment)
    c. Foresight of required measures to ensure resilience
11. Simulate and visualize results depicting risk levels, network islanding, resilient/non resilient CI elements, adaptation priority areas, engineering standards failure, adaptation measures ..

The implementation of the EU-CIRCLE approach is based on two basic tools. The first is the Methodological Framework, which defines the context and the steps for implementing the EU-CIRCLE process towards the definition of the CI resilience needs, due to climate hazards, extreme events and climate-change issues. The second is the Climate Infrastructure Resilience Platform (CIRP), which allow the integration of the EU-CIRCLE risk assessment (WP3) and the resilience (WP4) framework and which supports the implementation of the Methodological Framework in concrete cases allowing the end users to customize and apply it to their specific data and requirements. The methodological framework anticipates the cooperation among the different stakeholders of EU-CIRCLE including the CI owners/operators, the National Authorities in charge of CIP, the climate and climate change community and specialized hazard modelers.

According to the expected EU-CIRCLE outcome the stages of an indicative foresight scenario evaluation process using the methodological framework and the CIRP tools is described here next:

i. Authorities would like to consider long-term climate change impact to the essential services in a certain region (or at the country level) and for a specific time period in order to redefine planning and security policies.

ii. CI owners/operators are asked to participate in such a project integrating their data into the CIRP. Normally this would have been implemented by the National Authorities as regards the description and mapping of the assets and network of the national CIs. Thus the platform would have integrated default values of damage functions and resilience indicators for the various assets, which can be edited/modified/updated by the operators in order to be adapted to the specific infrastructure.

iii. Authorities and CI operators define jointly the extreme weather scenarios and the climate hazards that the envisaged project has to consider, based mainly on the region and the type of CI. These scenarios will determine the climate data required for the specific region and time period.

iv. Using the support of the EU-CIRCLE climate change modeling and eventual support of Climate-change experts, relevant datasets will be retrieved from external (e.g. CORDEX) or EU-CIRCLE (e.g. for the case studies) repositories to be used by CIRP.

v. There are two basic tasks that National Authorities can perform independently- using modelled climate data predictions and concerning Critical infrastructure protection:
   a. Reconsider the way of assessing the “return period” of specific climate events based on climate change model data and estimations (flood 100y return period is a representative example). Increase of weather and climate extremes in the future shall contribute to the reduction of the ‘effective’ return period event that existing infrastructures were built to withstand (Auld, 2008a).Thus a first issue EU-CIRCLE should consider can be the revision of the actual levels of protection related to the engineering standards corresponding to the return period of specific climate events. Using the available global and regional climate model datasets the NAs can redefine the return period of extremes of specific climate events during the planned lifetime of the infrastructure and revise eventually the respective values used for engineering its security and safety plans and;
   b. Redefine the spatial distribution of risk levels (zoning) related to specific hazards e.g. forest fires or floods, based on regional climate change model datasets. Relevant assessment of hazard likelihood (in the wider area and for the specific time period), based on such climate data projections can be used to delineate areas suited either for planning the deployment of specific CI assets or for assessing the risk related to the presence of such assets in areas where the risk level is expected to change in the future.

vi. Hazard modelers are provided with the envisaged environmental and climate scenario and are asked to produce relevant layers of potential climate-related damage drivers. These layers will be used as input into CIRP for assessing risk and elaborate resilience and adaptation options. EU-CIRCLE may also have intrinsic capability allowing the end users (National Authorities and CI operators) to access climate change data repositories and define related damage layers based on rule-based reasoning.

vii. CIRP will be used then to combine the spatial distribution of the CI assets, their attributes and damage curves together with the climate-related potential damage layers. The result will be to identify and locate, for the specific scenario, which particular assets will be at risk and which will be the relative consequences (total failure or relative service/performance loss) the climate damage driver will cause.

viii. CIRP will allow all stakeholders (NAs, CI operators and Climate hazard consultants) [8] to assess the climate consequences to the CI assets and network and to visualize the relative results at the asset level, the interconnected network level and the interdependent [9] networks level.

ix. The operators of different CIs will be thus able, using CIRP capabilities, to identify which specific asset and/or network link will be impacted under the specific climate scenario and which will be the consequences of such impact to the level of the provided essential service. Impact can be related to a number of concrete resilience indicators including time to recovery, to restore an agreed level of service etc.

x. Alternatives to address the aforementioned climate-driven damage potential using the respective resilience indicators, supported by CIRP, will be offered to the CI operators. This can be achieved by changing damage functions (retrofitting the asset), redesigning part of the physical network (e.g. repositioning assets) or managing its functional aspects (changing actual interconnections or interdependencies)

xi. At the end of this cooperative process the National Authorities and the CI operators can have a good knowledge depicted in a common picture, based on a documented approach on what the risks and the consequences of climate-driven damages may be in the specific area and for the envisaged time period. Therefore they can jointly identify the necessary countermeasures to be taken and the appropriate policies to be considered to address resilience challenges of the service provided.

A number of policy and operational questions relevant to the potential impact of climate change to critical infrastructure and the eventual consequences is provided in Annex I, at the end of this report. Similar questions and concerns may be addressed using the EU-CIRCLE tools, including the project methodological framework.

The methodological approach of EU-CIRCLE should also consider addressing the lack of currently available CI resilience modelling and risk assessment tools (e.g. consequence curves), providing relevant editors that may grasp the knowledge of the security experts and the operators of the critical infrastructures. This way, missing knowledge required to perform risk analysis can be completed by subject-matter expertise and expert's opinion.

The next chapters provide information concerning the study cases of EU-CIRCLE and an indicative context for implementing the methodological framework and use the CIRP tool as presented in D1.4 and fitted to each case study.

4 Climate change context of the EU-CIRCLE case studies

The study cases of EU-CIRCLE are presented in details in D 3.1. In this chapter, based on experience from past cases or contribution from the project stakeholders, a number of impacts to different infrastructures and related services are mentioned as well as lessons that stakeholders have been taught, which can be used in future protection and resilience plans. The document aims to investigate options and elements that may be tested and validated in context of the project demos and trials that will be performed during the final stage of the project in the pre-defined study areas.

Here next a rational concerning the climate-related risks and relative consequences to CIs as well as the related context concerning the specific case studies considered in the project is provided:

- *Case study 1: Extreme drought and very large forest fires in South France*

The case study area in southern France covers around 31,000 km², and has a population of five million. Inhabitants. Due to the Mediterranean climate and vegetation type the area is fire-prone, causing severe impact to local and regional communities. In recent years, there have been several fire incidents during which many dwellings lost connection to the electricity grid, road traffic was interrupted, transport safety jeopardized etc. Such events occurred in:

- May 2005 (1 event 500 000 burned area)
- July 2009 (1 event 200 000 burned area)
- December 2009 (2 events 100 000 burned area)

The relative case study of EU-CIRCLE occurs during the summer, when the population highly increases due to the presence of tourists, leading to overloaded flux of people on the railway and highways network. Moreover, the presence of tourists during this high risk fire season (which coincides with the touristic period) in the area, contributes to increased fire ignition probability.

In order to limit the fire extension, the following measures are considered often:

- Specific plans against natural hazards, especially clearing of vegetation
- Operational procedures to limit fire evolution along the railways, highways and electric networks (vegetation management)
- Fire detection and early warning systems
- Sprinkler systems and water-mist lines
- Conventions to cut very high voltage lines (up to 60% of 400 kV lines) in order to ensure the functioning of critical infrastructures as hospitals, nuclear plants, airport, railway, safety services
- Operational procedures for electricity network to prepare for unbalanced loads in case of line-cuts, put in operation the secondary hydroelectric power plants

The policy objective is to maintain the operability of the infrastructures during the event at an adequate level. A focus will be on prevention processes such as clearing along the highway and railway network or high voltage lines to limit the propagation potential and the power of the fire front. Another important aspect are protocols to restore to operations back to normality in a safe way for public and rescue services. The case study will elaborate on the following:

- Analysis of current prevention plans, interconnections between CI, inter-services collaboration, alert systems, legacy tools
- What are the weak points of the actual organization processes?
- How can we take into account the climate change impact in prevention plans?
- Identification and evaluation of measures to increase resilience of CI, avoid activity disruption and domino effects.

A meaningful time horizon for planning is 20 years. Relevant keywords related to resilience raised during the Consolidation workshop in Milan were: save lives, save valuables and: return to service.

The climate change related issues to this case study are summarized here next.

The IPCC reports (2007a [10],b [11] and c [12]) mention that major impact of climate change is quite likely to occur "via changes in the magnitude and frequency of extreme events, which trigger a natural disaster or emergency". In these reports is mentioned that the severity of the impact of the climate change in the coming years will be associated to the frequency of extreme weather events rather than the overall change in the so called average climate. *The size of forest fires and their frequency is expected to increase in South EU, which fact may lead to very large conflagrations or mega-fires with high probability and potential to have significant impact and consequences to the national critical infrastructures and their operation.*

- *Case study 2: Storm and Sea Surge in the Baltic Sea Port of Gdynia, Poland*

This case study foresees two distinctive scenarios:

The first scenario refers to **Oil Transport in Port**. The oil piping transportation system is operating at one of the Baltic Terminals that is designated for oil reception from ships, storage and sending by carriages and cars of the oil products. It is also designated for receiving from carriages and cars, store and load the tankers with oil products such as petrol and oil. On the basis of the piping system operation and safety statistical data coming from its operators its safety will be modelled, identified and assessed. The examination of the climate-change and extreme weather influence on the port oil transportation system safety will be performed within:

- The area in the neighbourhood of the port oil piping transportation system and
- The port oil piping lines which have a length of 25 km.

Under the assumption of the increasing stress of weather influence on the operation conditions in the form of maritime storm and/or other severe sea conditions, the piping system safety will be examined and the results will be compared with safety under the actual conditions. The piping system safety and operations optimization will be performed and practical suggestions and procedures improving its safety will be worked out. Within the focus of the examination are the following aspects:

- piping safety structure and its parameters,
- number of piping and its components safety states,
- piping components safety states changing and
- number of piping components leaving the safety state.

The second scenario is related to **Chemical Spill Due to Extreme Sea Surges**: The sea transport of dangerous chemicals is pretty safe in normal environmental conditions. However, the transported goods may be swept overboard as a result of bad weather and hard sea conditions. The released chemicals may be a threat for the crew and the ship while it is also a threat to pollute the seawater and the coast area. The Baltic Sea and nearby ecosystems are vulnerable to pollution and contamination and therefore to relevant sea accidents the transportation of dangerous goods. Nowadays, one major accident happens at the Baltic Sea every year approximately. There are more than 50,000 ships entering and leaving the Baltic Sea on a yearly basis and about 2,000 vessels are spotted in the Baltic Sea at any given moment. The experimental area that will be considered for the trials includes:

- The area in the neighbourhood of the maritime ferry route.
- The approximate length of the maritime ferry sea water route, which is equal to 250 km.

On the basis of the statistical data coming from reports on chemical accidents at sea, the risk of dangerous chemical accidents at sea and their dangerous consequences will be modelled, identified and predicted. Under the assumption of the climate stress on the operations in the form of maritime storm and/or other hard sea conditions, the risk of chemical spills at sea will be examined and the results will be compared with past results. The risk of chemical spills at sea and the management of the environmental degradation will be performed and practical suggestions and procedures for decreasing the risk of the environment degradation will be worked out. Within the focus of this examination are the following aspects:

Ferry safety states changing process data parameters includes:

- ferry technical system safety structure and its parameters identification
- number of ferry technical system and its components safety states and their definitions
- numbers of ferry technical system components leaving the safety state

Consequences of an accident to the critical infrastructure will be considered by implementing the following three interacting and interdependent processes:

- the process of initiating events
- the process of environment threats and
- the process of environment degradation

The time horizon for considering resilience planning is up to 100 years. Relevant key words related to resilience that were raised during the consolidation workshop are: strength, elasticity, insight (awareness).

This specific case is rather associated to potential environmental problems of marine pollution due to extreme weather events (storm surge) rather than to its relevant impact to critical infrastructures. Issues related to climate change that may be associated to this case study are summarized here next.

The effects of climate change on storm surge are two-fold i.e. a. changing storm frequency and severity in a given location and b. sea level rise providing a higher “launch point” for surge even if storm frequency and severity remain constant.

Storm surges and falls are defined as short-term, extreme variations in the sea level. Such short term variations refer to changes of the sea level recorded within several minutes to a few days. They include sea level oscillations intermediate between wind generated waves and seasonal sea level changes. The coastal protection services describe a storm surge as a dynamic rise of the sea level above the alarm or warning level, induced by the action of wind and atmospheric pressure on the sea surface.

Situations are linked with a lowered atmospheric pressure system (a tropical cyclone or a concentric baric low) which overlies a sea water cushion, the so-called baric wave, moving together with the pressure system at the sea surface. The wave's height depends on the pressure decrease in the centre of the system. A pressure drop of $\Delta p = 1$ hPa results in a static sea level rise of $\Delta Hs = 1$ cm at the stationary low (Figure 4a, Formula 1). When the low moves over the sea surface, the latter becomes dynamically deformed (ΔHd). The sea level deformation associated with the baric wave shows positive wave elevations in the centre and negative elevations on the flanks of the deformation (Figure 4b, Formula 2). During the passage of a deep low, the sea level rise may be 2–4 times higher than the rise produced by static conditions. The fluid level deformation moves according to the laws of forced long wave propagation. When the wave propagation velocity is close to that of a baric system passage, the wave amplitude will reach large values under the dynamic parameters of the system.

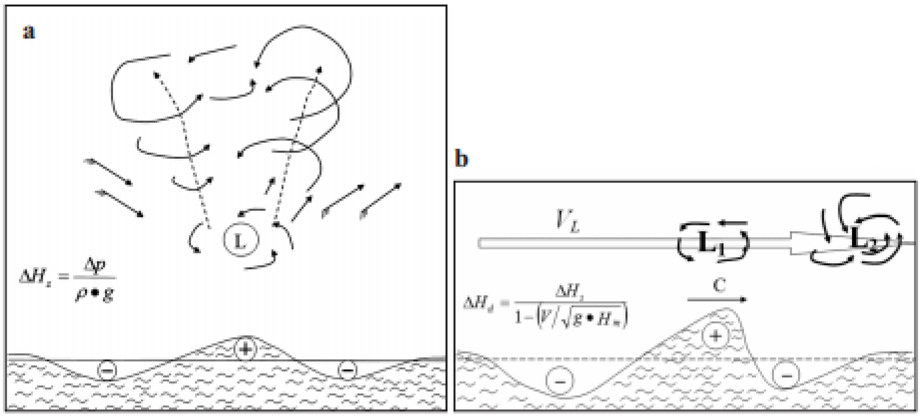

Figure 4. Diagram of sea surface deformation caused by a low pressure system: static (a) and dynamic (b) sea surface deformation (Source: B.Wisniewski and T.Wolski - 2011)

Besides, an additional disturbance taking the form of diverging transverse waves is propagated perpendicularly to the passage trajectory of the baric system. The waves look like those generated by a ship's movement. The amplitude of these additional disturbances should be expected to be lower than that of the basic sea level deformation caused by the baric wave. In addition to the major forced wave, i.e. the wave propagating at the speed of the baric system, there can be additional free long waves associated with the rapid change in the baric low velocity or direction.

Thus, storm-generated surges and falls of sea level are a net effect of wind action and a baric wave resulting from the baric field characteristics. Wind and a baric wave can produce the same effect, i.e. both factors cause the sea level on the coast to rise or fall; they can also produce opposite effects, when one factor raises the sea level and the other lowers it. The effects of a baric wave may be several times greater than those of the wind action. When the storm (baric wave, wind) abates, the sea level – knocked out of balance – will undergo free damped oscillations until equilibrium is restored (seiche-like variations).

Owing to the complexity of the phenomenon, any sea level forecast during a storm surge will be problematic. An additional difficulty is that sea level changes are greatly affected by local conditions on the coast and the seafloor relief in the inshore zone and in a port. Therefore, it is necessary that the sea surface deformation factor by the rapidly moving baric low be included in future models developed to forecast storm surges and falls.

Since storm surges are related to the sea level it has to be considered that scientific findings summarized by the Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4) (Intergovernmental Panel on Climate Change, 2007) indicate that global warming, due in large part to human releases of GHGs, will accelerate global mean sea level rise. In particular: Projected warming due to the emission of GHGs during the 21st Century will contribute to sea level rise for many centuries; Sea level rise due to thermal expansion and the melting of ice sheets could continue for centuries or millennia, even if greenhouse gas emissions were to be stabilised; Sea level rise was not geographically uniform in the past and will not be in the future; and There is a great uncertainty associated with the magnitude of global warming. If sustained, it could lead to the elimination of the Greenland Ice Sheet. In recognition of this uncertainty, IPCC AR4 sea level rise projections do not account for the accelerated outflow of ice sheets. Climate scenarios examined by the IPCC project a global mean temperature increase of 1.1°C to 6.4°C by 2100. The corresponding sea level rise, excluding future rapid dynamical changes in ice flow, is 18 cm to 59 cm by 2100. Global sea level is projected to rise another 1 to 4 feet by 2100 (Fig.5). Relative sea level rise will be greater along some coasts because of subsidence (e.g., in Torbay area), which will have a significant effect on low-lying transportation infrastructure near the coast.

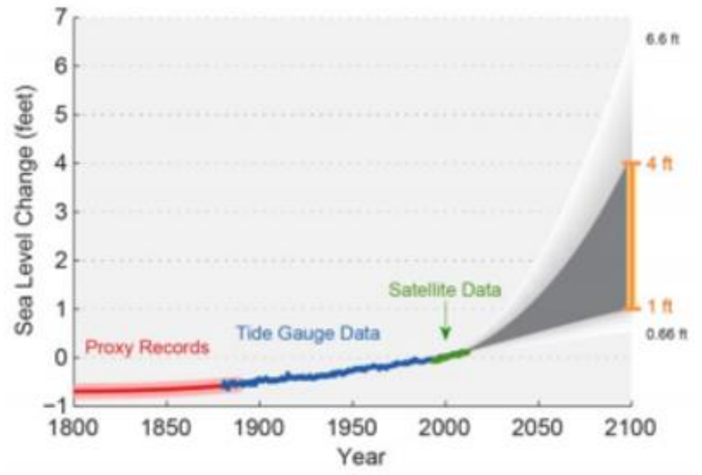

Figure 5. Observed and possible future amounts of global sea level rise from 1800 to 2100, relative to the year 2000

In the Atlantic, the frequency of the strongest tropical storms (Category 4 and 5 hurricanes) is expected to continue increasing.
At the same time, a slight decrease in the total number of tropical storms is projected by climate models; however, these projections are subject to considerable uncertainty. And these projections do not specify if the risk for land-falling storms will change. Regardless, rising sea levels will enhance the potential damage of future storms.

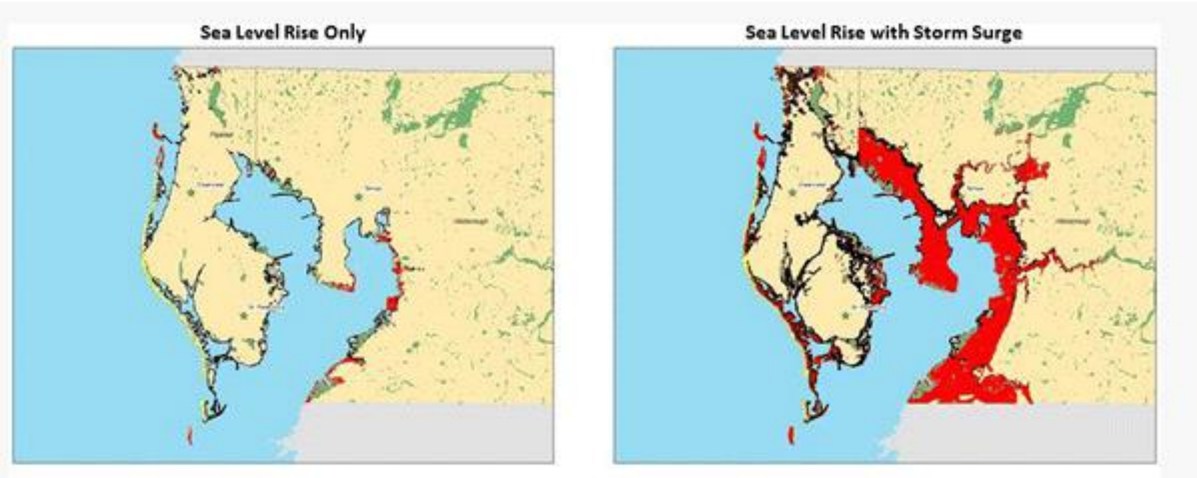

Figure 6. Effect of incorporating storm surge in economic impact estimates for Tampa, Florida

In an award-winning *Environmental Research Letters* paper [13], Tebaldi et al. projected the future effects of sea level rise on storm surges (Fig. 6). By combining future global sea level rise with historic tide gauge water levels at 55 sites, the authors found that for about 1/3 of the areas considered, today's "once in a century" storm surges may become "once in a decade" storms in future.

- *Case study 3: Coastal flooding across Torbay, UK*

Torbay Borough is located in the South West of England and covers an area of approximately 62 km2. The main settlements within Torbay are Torquay, Paignton and Brixham. The main economic driver for Torbay is the tourism industry, which has developed around the coast line. The region has suffered flooding over many years, from different sources including surface water runoff, highway flooding, sewer flooding, main river and ordinary watercourse flooding during intense rainfall events. Coastal areas of Torbay suffer coastal flooding due to overtopping of sea defences during high tides that coincide with easterly winds. All sources of flooding in the low lying areas of Torbay are exacerbated during high tides and heavy rainfall when capacity of outfalls discharging to coastal waters are reduced.

The climate change related issues to this case study are summarized here next.

Most of the important cities of large islands or islandic countries are located by the coast. Likewise, much of industrial and critical infrastructure is coastal, notably power stations, communications and transport hubs. All relevant assets are therefore at risk from coastal floods and storm surges and, in the long-term, from rising sea levels and coastal erosion. In these situations a flood risk assessment should be carried out formally for each critical infrastructure asset. The assessment should identify its frequency of exposure to a concrete hazard, its resilience to exposure and the consequences of its failure. Thus adequate adaptation measures can be identified and, by subjecting each to technical, economic, social and environmental analysis, prioritise them.

This is the context of addressing the relative requirements of the third case study of the project, related to coastal flooding risk across Torbay in U.K. The consortium shall cooperate with local stakeholders to implement the EU-CIRCLE methodological framework and the CIRP tools.

- *Case study 4: International Event*

The international event exercise has the objective to test the applicability and compliance of the EU-CIRCLE methodology and the compatibility of CIRP in countries outside EU and in non-European operational context.

The international study case has two elements. One is the exploratory study phase that is targeted at learning of the case study context and the current capacity requirements and capacity development gaps in terms of critical infrastructure resilience. The other phase is the dissemination phase where learning from the EU context is disseminated at various levels as an international dissemination.

- *Case 5: Rapid winter ice melting and floods around Dresden, Germany*

Warmer weather can bring flooding because of rapidly melting snows and ice jams on local rivers. Melting snow piled-up along roadways may also cause the water to pool on the highway creating a driving hazard. Additionally, colder temperatures at night will create ice on the highways.

As temperatures rise, snow and ice melt and increase the risk of flash flooding. Significant snow accumulation and freezing can often make conditions ideal for flooding as temperatures warm–particularly rapid rises. A deep snowpack increases runoff produced by melting snow. Heavy spring rains falling on melting snowpack can produce disastrous flash flooding. Thick layers of ice often form on streams and rivers during the winter. Melting snow and/or warm rain running into the streams may lift and break this ice, allowing large chunks of ice to jam against bridges or other structures. This causes the water to rapidly rise behind the ice jam. If the water is suddenly released, serious flash flooding could occur downstream. Huge chunks of ice can be pushed onto the shore and through houses and buildings.

The effect of snowmelt on potential flooding, mainly during the spring, is something that causes concern for many people around EU. Besides flooding, rapid snowmelt can trigger landslides and debris flows. In alpine regions like Switzerland, snowmelt is a major component of runoff. In combination with specific weather conditions, such as excessive rainfall on melting snow for example, it may even be a major cause of floods. In Switzerland, snowmelt forecasting is being used as a flood-warning tool to predict snowmelt runoff and potential flooding.

5 Reference to past and relevant cases

5.1 Case study 1: Extreme drought and very large forest fires in South France

France, 30-31st July 2014

30th July 2014: a forest fire ignites near Narbonne town, South of France, leading to the cutting of the main motorway (A9) linking France to Spain during 5 hours. Moreover, the electric networks was cut as the high tension line crossed the fire. 6000 homes were without electricity during several hours.

31th July 2014: 60 kilometres far from the fire of the day before, a new fire ignition occurred near the same motorway. The traffic was cut in both ways, leading to 8 kilometres of traffic jam. Specific road accesses were opened by the motorway operator, but the secondary networks were quickly saturated.

The consequences of those fires did not lead to dramatic problems. Even if people were angry as they had to wait during hours on the road, the crisis management occurred in a safe way.

No specific data were used to establish the link between weather and consequences for motorway and electricity network.

France/Spain frontier, 22nd July 2012

A forest fire ignites near the French-Spanish frontier (Fig. 7), leading to the interruption of the highway on both directions during several hours. The railway was stopped too. Four people died, thirty were injured. Three people died as they were blocked on the road, surrounded by smoke. Cross-border problems occurred during the crisis situation.

Figure 7. French-Spanish border forest fire of 2012

No specific data were used to establish the link between weather and consequences for motorway and railway network.

Peloponnesus Mega-fires in Greece, 24-28th August 2007

A relevant example of very large wildfire in order to investigate the impact of a climate-related hazard to critical infrastructure and to the economic and societal resilience is the case of the Greek mega-fires of 2007. The 2007 Greek forest fires were a series of massive forest fires that broke out in several areas across Greece throughout the summer of 2007. The most destructive and lethal infernos broke out on 24 August, expanded rapidly and raged out of control until 27 August, until they were put out in early September. The fires mainly affected western and southern Peloponnese as well as southern Euboea island. The death toll in August alone stood at 67 people. In total 84 people lost their lives because of the fires, including several fire fighters.

One of the most critical impacts to essential services during the 2007 firestorm was the consequences of the fire to the road transport network of Peloponnese. While fires mostly destroyed forests and farmland areas, they significantly influenced traffic circulation due to various link closures and affected the operability and functionality of the national and local road network.

Shortly after the fires broke out, gradual closures of parts of the road network that were characterized as unsafe were observed. During August 25, the fires rendered 1,054 km of road network out of use, with the events and their impacts on the road network gradually declining afterward. Closures of specific parts of the network occurred either following police orders, based on information about the proximity of the fires to inhabited villages, or due to the fires themselves that affected parts of the road network (Kapakis 2007) [14]. Traffic management measures were also applied, in order for people to be able to evacuate, while the authorities ordered the detouring of trips destined to unsafe locations. The temporal character of all measures applied during the 4-day summer period depended on the severity of the event in the respective area. The length of the closed roads during the August 2007 fires in Pleoponnese is shown in Figure 8.

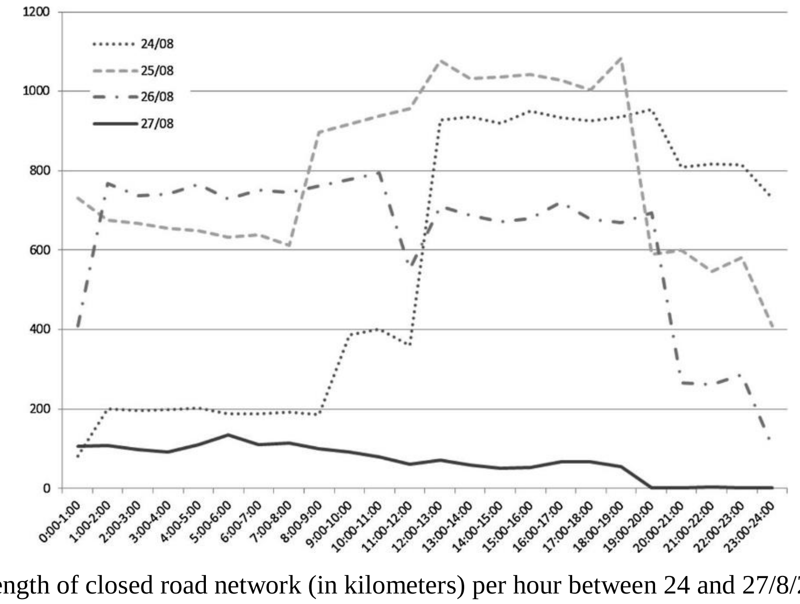

Figure 8. Length of closed road network (in kilometers) per hour between 24 and 27/8/2007 in Peloponnese

The hourly link closures between 24 and 27 August 2007 are shown in Figure 9.

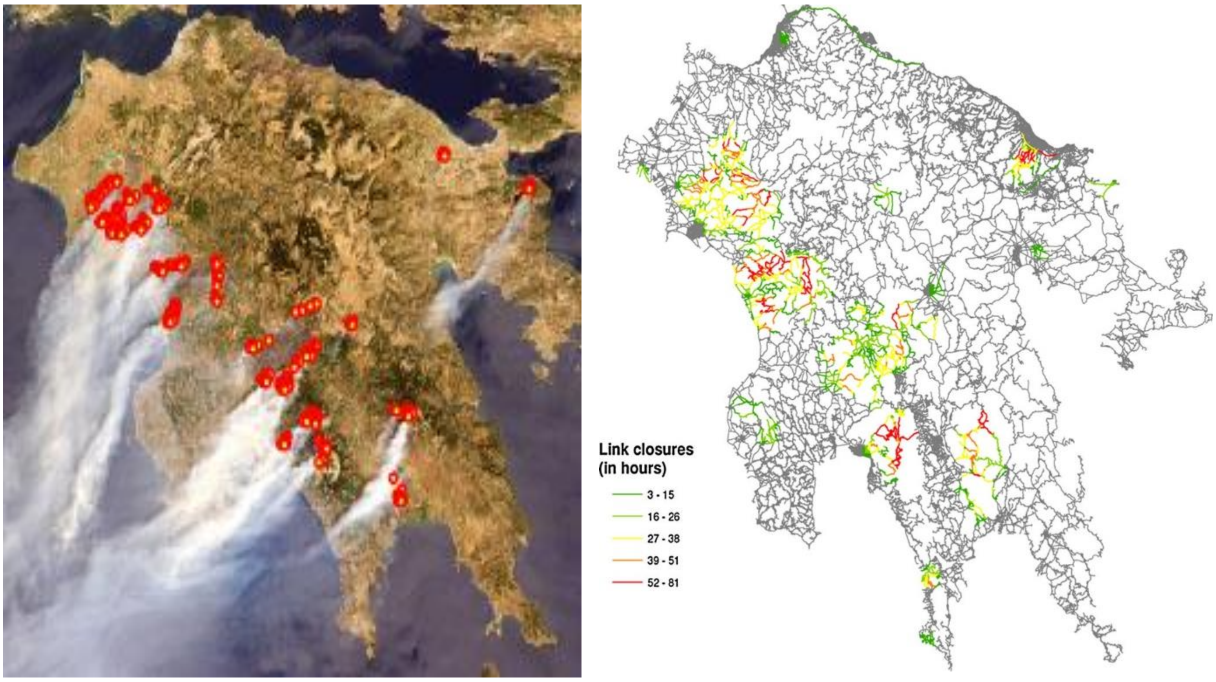

Figure 9. Fire activity [15] and hourly link closures [16] for the period between the 24 and 27 of August 2007

As shown in Table 1, during the late August of the 2007 fire season, 55 people were killed by the fires. The health system addressed an increase of the normal patient flow and multi-casualty situations between the 24/8 and 31/8/20017. Another 2,094 people were accepted by the hospitals of the regional health system due to the fires within less one month (Statheropoulos 2008) [17]. Between the 24 and 27 of August, the event peaked in terms of severity and seriously affected also the capability, sufficiency and performance of the rescue services.

Table 1. Health impacts in the Peloponnese region during the summer of 2007 (Statheropoulos 2008)

Date	Respiratory problems	Ocular problems	Burnings	Cardiopulmonary problems	Number of patients	Deaths
17/08	20	2	3	6	50	0
18/08	19	4	1	13	45	0
19/08	17	4	2	16	59	2
20/08	26	5	1	19	74	0
21/08	29	3	2	18	70	0
22/08	18	2	3	25	72	0
23/08	28	3	3	15	92	0
24/08	52	9	14	14	115	0
25/08	149	68	28	8	285	45
26/08	79	64	15	14	199	1
27/08	76	21	14	18	159	7
28/08	50	15	8	18	115	0
29/08	21	4	6	18	70	1
30/08	34	4	6	18	81	0

31/08	30	5	5	11	80	1
1/09	17	6	9	14	67	0
2/09	14	4	0	14	38	0
3/09	21	1	4	12	63	0
4/09	18	5	4	11	60	1
5/09	26	2	5	20	72	1
6/09	16	3	1	13	50	0
7/09	10	0	2	13	35	0
8/09	10	1	2	9	38	1
9/09	17	0	1	16	45	1
10/09	18	5	0	14	60	0

Apart from the health sector, the impacts on residences and other infrastructure were also severe.

Concerning the economic impacts of the fires the estimation for the cost of the damages for the 500,000 people affected was close to 3 billion euros according to European sources (Davidson 2007) [18], while other moderate estimations have found it to be close to 2.2 billion US dollars (USAID 2007) [19]. The overall operational costs were estimated as 600,000 euros as 20 % of the country's olive trees were located within the affected Peloponnese region, with the area representing 4.5 % of the nation's annual GDP (Davidson 2007). In addition to the direct costs of the events, the cultural tourism sector was also hit, since the blazes reached the proximity of the Ancient Olympia and affected a series of accommodation units.

5.2 Case study 2: Storm and Sea Surge in the Baltic Sea Port of Gdynia, Poland

Extreme sea levels – storm-generated surges and falls – on the Polish coast are usually the effects of three components: the volume of water in the southern Baltic (the initial level preceding a given extreme situation), the action of tangential wind stresses in the area (wind directions: whether shore- or seaward; wind velocities; and wind action duration), and the sea surface deformation produced by deep, mesoscale baric lows moving rapidly over the southern and central Baltic that generate the so-called baric wave.

Storms and the associated surges have been described and analysed in numerous publications; the most comprehensive descriptions in the Polish literature are those of Majewski et al. (1983), Majewski (1986, 1989, 1997, 1998a,b), Sztobryn et al. (2005, 2009) and Wiśniewski & Wolski (2009). The relevant literature emphasizes the contribution of the wind field to sea level variations, particularly during storm situations. On the other hand, tidal effects are irrelevant for sea level changes in the Baltic (Suurssar et al. 2003, 2006, Jasińska & Massel 2007). These publications and annual records have served as a basis for a summary of historical data [20] on extreme sea levels along the Polish coast (Table 2). The table shows that in the case study area of EU-CIRCLE (Gdynia) a maximum sea level rise observed (132cm above the zero tide level) in November 2004.

Table 2. Extreme sea levels (cm) along the Polish coast (tide gauge zero=5—cm N.N.)

Tide-gauge	Maximum sea level [cm]	Date of occurrence	Minimum sea level [cm]	Date of occurrence
Świnoujście	696	10 Feb. 1874	366	18 Oct. 1967
Dziwnów	615	10 Feb. 1874	410	4 Feb. 1960
Kołobrzeg	722	13 Nov. 1872	370	4 Nov. 1979
Darłowo	659	9 Jan. 1914	393	10 Feb. 1897
Ustka	668	15 Dec. 1898	396	10 Feb. 1897
Łeba	668	15 Dec. 1898	403	31 Dec. 1890
Władysławowo	644	23 Nov. 2004	412	4 Nov. 1979
Hel	622	14 Jan. 1993	405	Jan. 1904
Gdynia	632	23 Nov. 2004	414	Feb. 1937
Gdańsk	664	16 Dec. 1843	395	20 Jan. 1887
Świbno	702	5 Dec. 1899	413	10 Feb. 1897

Three relevant past cases are presented here next in order to draw conclusions and extract lessons that may be integrated into the EU-CIRCLE conceptual framework.

5.2.1 The storm of 16–18 January 1955

A very active low pressure system which advected over the southern Baltic produced a rapid sea level rise. This system passed from the south of England via the North Sea coast to the southern Baltic coast, from where it moved on to the Gulf of Finland. The high horizontal pressure gradient component in the western part of the system was accompanied by a strong, gusty, north-westerly wind. The entire Polish coast experienced a rapid sea level rise (maximum of 617 cm, i.e. 117 above zero N.N., at Świnoujście on the western part of the coast, 635 cm at Kołobrzeg, and 615 cm at Gdańsk on the eastern part of the coast) (Figures 1b, c). The low was moving from over the Pomeranian Bay towards the eastern part of the coast with a mean velocity of 50 km h−1 and passed over the Polish coast in the space of 6 hours. The low pressure system's velocity affected not only the magnitude of the sea level rise, but also its intensity. All the gauges showed only the positive phase of the sea surface deformation. On 17 January 1955, the wind at Świnoujście changed direction from S to SW and NW, and could not, by itself, have generated the surge.

5.2.2 The storm of 17–19 October 1967

A deep and active low pressure system from over the British Isles was moving at a velocity of 70 km h−1 over Denmark and southern Sweden, the Baltic Sea and on towards the north-east into the White Sea. The storm wind and baric wave generated by the system induced extremely large variations in the Baltic sea level. The rapid passage of the low over the Baltic resulted in a characteristic sea level fall on the Polish coast on the morning of 18 October. At Świnoujście, the absolute 1946–2006 minimum of 366 cm was recorded. The low's centre moved that day over the ˚Aland Archipelago. For some hours the southern Baltic, left in the rear of the baric system, experienced severe north-westerly and northerly winds. The return to equilibrium proceeded through wind-induced seiche-like changes in the sea level. At Świnoujście and Kołobrzeg, the sea level changes during 8 h had an amplitude of about 2 m.

5.2.3 The storm of 13–14 January 1993

On 14 January, an active low pressure system, the so-called ‘junior’, passed – along with atmospheric fronts – from over the North Sea via the Danish Straits into the Baltic. The atmospheric low was as deep as 972 hPa. Typical of the sea level changes during that storm was the large amplitude of variations in the eastern and western parts of the coast. The sea level rises and falls, moved eastwards in parallel with the low centre passage. The storm surge involved a sea level deformation by the baric wave with its positive and negative phase. Significant here was the high velocity (about 115 km h^{-1}) of the low’s passage, which greatly affected the wave’s dynamic component involving a ratio between the passage velocity and the depth of the area ($VL \gg \sqrt{gHm}$). An important feature of the storm surge in question was the very rapid rise and fall of the sea level, which is of significant practical importance for forecasting the under-keel clearance when a ship enters or leaves a port. The storm lasted for scarcely 5 hours, but in that time caused severe damage on the coast and triggered the Jan Heweliusz ferry disaster at sea.

5.3 Case study 3: Coastal flooding across Torbay, UK

The area of case study 3 is sited in Torbay borough in UK (Fig.10). Historically flooding events have resulted in many residential and commercial properties being flooded throughout Torbay. In addition, numerous roads are affected during the flooding incidents and the main coast road linking Torquay to Paignton and Brixham has to be closed on a regular basis due to overtopping of the sea walls. The most severe flooding event over the last 20 years occurred on the 24th October 1999 when over 200 properties were flooded, many roads had to be closed to traffic and critical infrastructure was disrupted. As Torbay relies on tourism for its economy, flooding has a very significant economic impact.

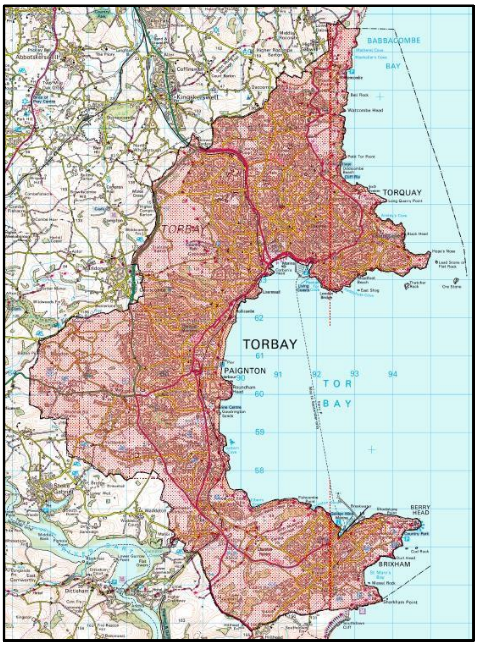

Figure 10. Area of case study 3 - Torbay borough.

Another example of damage to critical infrastructure as a result of storms was in 2013 when during a severe storm the sea wall at Livermead in Torquay was breached. As a result of this breach, the main highway linking Torquay to Paignton had to be closed and the sewage system that transfers all of Torquay‘s sewage to the sewage treatment works failed. Also, a high pressure gas main was damaged however failure of the main was averted by the installation of sheet piling to protect the main from further damage. If this had not been successful, all residents and businesses within a larger radius would have had to be evacuated.

Other cases in the past

During spring 2013, severe flooding affected several central European countries such as Austria, the Czech Republic and Germany. Transport and supply chains were severely disrupted in many areas, sometimes for a long time:

- The main railway bridge across the River Elbe in Germany, servicing all trains to and from Berlin via Hannover, including the important high-speed services Berlin–Frankfurt and Berlin–Cologne/Dusseldorf, was affected and remained closed until early November 2013. This led to disturbances in the whole network.
- In Austria, rail service was heavily impacted on the Brenner crossing, which had to be closed for more than a week. This closure led to disruption for long-distance trains from Germany to Italy via Austria.
- Due to high water, several waterways including sections of the Rhine, Neckar, Main and Danube and the Rhine-Main–Danube Canal had to be closed for merchant ships, leading to disruption in some supply chains.

Figure 11. Damage to the railway at Dawlish in Devon, U.K. (within the UK Case study of EU-CIRCLE)

The winter of 2013/2014 saw exceptional weather affect the United Kingdom, with a run of winter storms culminating in serious coastal damage and widespread, persistent flooding (Fig.11). During this period of exceptional weather, the transport system was among the most severely affected elements of infrastructure, with flooding and other damage to rail and road infrastructure, closures of railway lines and suspension of services for commuters, cancellation of flights and ferries, and other consequences. Perhaps the most iconic event was the severe damage to a coastal section of the south–west main line railway at Dawlish, Devon during the storms in February 2014. This event saw the railway in the south-west of the United Kingdom cut off from the rest of the railway network for two months. In general, it is not yet possible to attribute to climate change the occurrence of particular high-impact weather events, though progress is being made in this area (IPCC, 2013). However, it is clear that the projected increase in the frequency and intensity of some extreme events increases the need to properly prepare for such situations. During the winter floods in February 2014 in the UK, the coastal section of the south–west main line railway was destroyed in Dawlish, Devon, in the south west of England. The railway in the south-west of the UK was cut off from the rest of the network for two months.

A recent storm in UK, labelled a "weather bomb" by some media outlets, led to the suspension of many ferry services in Scotland and Northern Ireland as a result of waves over 10 metres high. Rises in sea-levels is also an increasing threat to harbours and other transport infrastructure and services at the coast.

Aside from storms and floods, transport networks are likely to face increasing threats from rising temperatures. Unusually high temperatures and extended heatwaves can increase the problems of rail buckling, pavement deterioration and passenger discomfort.

Since a railway infrastructure is present in the area of Devon (UK case study area of EU-CIRCLE) Table 3 [21] shows the relations between climate effects and railway infrastructure.

Table 3. Relationship between climate effects and railway infrastructure

Climate Factor	Expected Climate Change	Impact on Railway Assets	Impact on Railway Performance
Temperature	High temperatures and heat waves Sudden temperature changes Intense sunlight	Signal failures Track buckling Slope fires Bridge deformations Overheating of tunnels	Decrease of safety
Precipitation	Intense rainfall Extended rain periods Drought	Damage to embankments Failure of drainage systems Flooding in tunnels and over bridges Scour at bridges Earthworks failures Faster plant growths, new plants	Decrease of availability
Wind	Higher wind forces Coastal storms and sea level raise	Damage to installations, catenary Restrictions / disruption of train operation (dewiring) Damage to embankments and earthworks Deterioration of structures – bridges and tunnels (corrosion, wind forces)	Increase of maintenance costs
Lightning strikes and thunderstorms	Increased number of thunderstorms	Damage to catenary and signaling	

5.4 Case study 4: International Event

Bangladesh is highly vulnerable to climate-induced hazards and disasters and its coastal part are mostly threatened for the impacts of climate change. In broad terms Cyclone Aila, which hit Bangladesh in May 2009 is selected as the case study in context of the EU-CIRCLE project. Torrential rains from Aila resulted in 190 fatalities and at least 7,000 injuries across the Khulna and Satkhira Districts. Across 11 of the nation's 64 districts, approximately 600,000 thatched homes, 8,800 km (5,500 mi) of roads, 1,000 km (620 mi) of embankments, and 123,000 hectares (300,000 acres) of land were damaged or destroyed. Approximately 9.3 million people were affected by the cyclone, of which 1 million were rendered homeless. One year after the storm, 200,000 people remained homeless. Total damage amounted to 18.85 billion taka (US$269.28 million).

5.5 Case 5: Rapid winter ice melting floods around Dresden, Germany

Dresden is the largest city in the Eastern part of Germany, Saxony, near the Czech border. It is crossed by the large river Elbe (its width is around 110m in Dresden) which comes from the Czech Republic and flows through Magdeburg and Hamburg into the North Sea. The region between Dresden and the Czech border, but also in the East and South-Western surroundings of Dresden are occupied by hills and mountains high up to ca. 1200 m. In the recent past, a number of significant flood events occurred (particularly notable are the floods in 2002 and 2013) in the Central Europe, which were caused by intense and long-lasting rains leading to extreme floods. The June 2013 floods in Germany damaged the main railway bridge across the River Elbe, used by all trains to and from Berlin via Hannover, including high-speed services from Berlin to Frankfurt, Cologne and Dusseldorf.

According to the Floods directive (2007/60/EC), flood hazard and risk maps, which are considered as input layer to EU-CIRCLE, refer to three major scenarios as follows:

- Floods with low probability, or extreme event scenarios (e.g. 500 years return period)
- Floods with a medium probability (return periods of 100 years or more)
- Floods with a high probability (e.g. 20 years return period)

Flood extent, water depth and water flow are parameters expected to be displayed in such maps. The maps may help to zoning the exposure of flood-sensitive infrastructure elements and therefore identify which existing infrastructure is under risk or which might be at risk if it would be built within an area of potential significant flood risk. An assessment of the infrastructure's risk exposure and vulnerability to climate change impact shall guarantee its long-term sustainability.

Figure 12. Map depicting the geographic extent of the 2013 floods in Central Europe

It has to be underlined that the floods of the years 2002 were related to flash floods while the floods of 2013 correspond to plain flood. Critical infrastructure of river cities experience important damages during plain floods. Shipping is halted, great part of the road network is out of use, while emergency services such as fire stations can be submerged under water.

In the second week of August 2002 unusually intense rain and violent thunderstorms (a situation later become known as Cyclone Ilse) caused high waters and floods in many parts of Europe, killing dozens, dispossessing thousands, and causing damage of billions of euros in the Czech Republic, Upper Austria, Bavaria, Slovakia, Poland, Hungary, Romania and Croatia (Fig.12). The cyclone arrived in the mountains of Dresden on the 10th of August 2002. More than 100 litres per square metre rain at night caused small mountain streams to collapse and water reservoirs to be overfilled. The rain recorded between the 12 and 13 of August 2002 (24h) equalled a third of the yearly average and the flood profile has a magnitude expected to occur roughly once a century. Several rivers in these Central-European regions, including the Vltava, Elbe and Danube reached record highs.

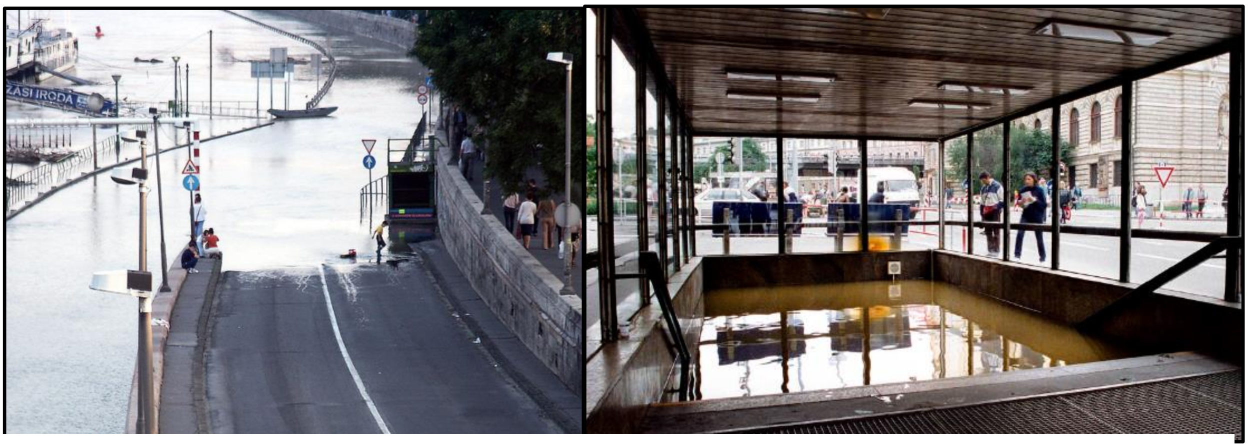

Figure 13. Impact of 2002 floods in Budapest roads (left) and Prague metro (right)

Flash floods are originated high in the mountains where the capacity of the network of small streams can transport efficiently the precipitation water only during the normal rain days. In case though of heavy rainfall these streams are rapidly overwhelmed, they become quite larger due to the water quantity that they receive and they change their usual course causing damages to assets sited along their path. Villages in Northern Bohemia, Thuringia and Saxony were heavily damaged by rivers changing their courses or massively overflowing the river banks. Due to the quantity of water and the speed of the run-off the rivers change their courses in unexpected ways and their water ravaged transport infrastructure and networks in several cities. The Prague Metro subway system, suffered significant damages and great part of it was completely flooded (Fig.13). Dresden experienced significant damages as soon as the Elbe River reached an all-time high of 9.4 meters. The huge amount of water caused destruction all the way between the mountain villages at the summit of the Erzgebirge (Ore Mountain) to the cities located in the valley of the River Elbe. The usually small River Müglitz caused many villages to be isolated for hours and to destroyed to a very large extend most of them. More than 30,000 people were evacuated from various neighbourhoods throughout the city and some of the city's cultural landmarks were considered to be at risk.

A more severe problem was presented by the evacuation of Dresden’s hospitals. Four out of six major hospitals in Dresden are located at the close reaches of the River Elbe and were affected by the flooding. On the morning of 13th, a complete electric power and communication failure cut off the hospital complex Dresden-Friedrichstadt from the city. Within a few hours, the evacuation of about 950 patients had to be organised without the help of computers and telephones despite the limited transportation capabilities. Nevertheless, because of its central location within Dresden’s flooded areas and the probability of injuries amongst rescue workers, emergency medical treatment had to be maintained. After evacuation was completed on the afternoon of August 13, regular medical treatment was not possible until the 21st of August.

Nevertheless, the hospital evacuations should give reason to think over the physical arrangement of hospital equipment and the general management of such a crisis. Some severe problems resulting in the failure of the hospital’s ability to keep up medical treatment during the flood were caused by the fact that the possibility of heavy floods had not been an issue of serious attention. Necessary technical equipment, such as electric power, telephone and computer network distribution devices, were installed mostly under earth basements because of space consideration. With the second flood wave, the rising groundwater-level caused all this technical equipment to malfunction or to break-down completely. Some believe that these factors contributed to the arising necessity of evacuating hospitals in the course of flood events in the first place. In fact, a hospital with autonomous power supplies does not need to be evacuated at all.

Once the water levels returned to normal and residents returned to their home, they faced not only the damage left by the rising waters but also threats of disease due to decaying waste and food. The damage increased due to flooding of sewage treatment plants and the risk of damage to chemical plants.

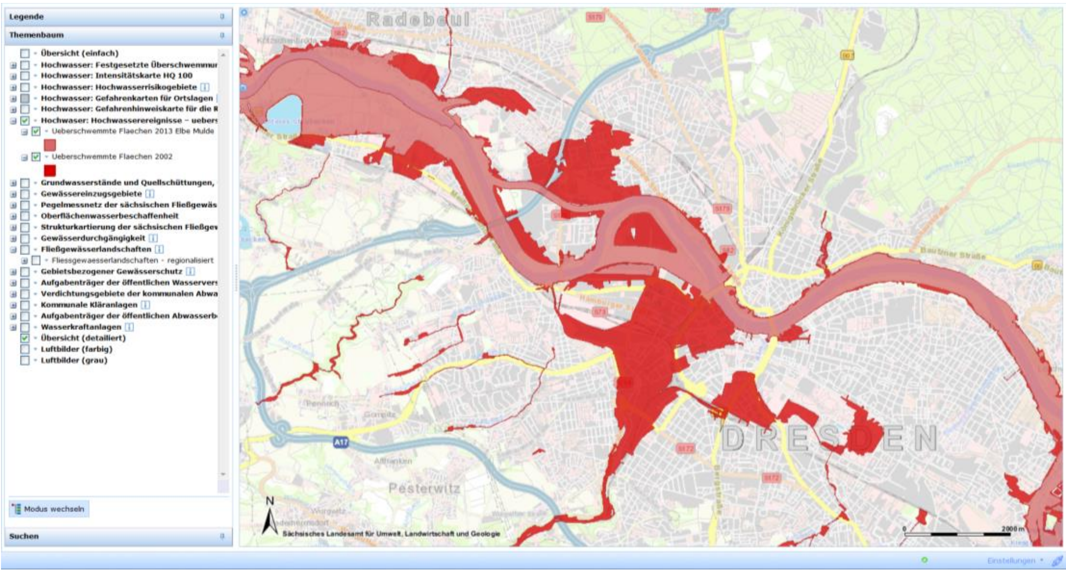

Figure 15. Flooded areas ‘2002 and ‘2013 in the City of Dresden. Source: LFULG Sachsen (http://www.umwelt.sachsen.de).

The plain floods of 2013 began after several days of heavy rain in late May and early June in Central Europe, which led to high water level in rivers that ran through cities sited in flat areas. The floods primarily affected the south and east German states (Thuringia, Saxony, Saxony-Anhalt, Lower Saxony, Bavaria and Baden-Württemberg), the western regions of the Czech Republic (Bohemia), and Austria. In addition, Switzerland, Slovakia, Belarus, Poland, Hungary and Serbia (Vojvodina) were also affected by floods but to a lesser extent.

In Dresden one of the bridges across the Elbe river was closed to traffic, while in the city of Magdeburg, authorities declared a state of emergency, expecting the Elbe river to exceed the water level of 2002 (Fig.15). With the water level rising five metres above the normal level approximately 23,000 residents had to leave their homes on 9 June.

Similarly in the area surrounding the city of Leipzig, some 6,000 people had to be evacuated on 4 June. Furthermore in Zwickau (Saxony) the Volkswagen factory had to stop its car production, with damage done to transport infrastructure raising fears that suppliers would not be able to deliver their products in time. The factory was able to resume production by 4 June. Furthermore the German armed forces were able to protect chemical production facilities in the Middle German Chemical Triangle from the floods. In terms of damage insurance industry specialists stated that insurance losses were less than during the 2002 floods, although some areas experienced higher waters, since investments for flood defences over the previous ten years were proved quite efficient. Twenty-five deaths were recorded as a result of these floods; eleven in the Czech Republic, six in Austria, and eight in Germany.

Figure 16. Road breach in Bitterfeld following the flood

In these regions there are often roads going through valley which are vital in a sense that if they are not available any more, quite long bypasses have to be taken (Fig.16). Additionally railways, especially railway bridges, are often affected as well (Fig.17). These two aspects show the impacts on the transport network.

Losses and damages from the flood of 2002 are as follows (Kraus, 2012):

Figure 17. Damage to the front (left) and back (right) side of a bridge basement next to the 2013 flood

- Casualties: 21
- Damage costs: 8,6 Billion EUR
- Damaged buildings: >25,000; 400 totally destroyed
- Damaged roads: 540 km
- Damaged social facilities: 280
- Evacuations from the city of Dresden: 35,000

In the aftermath of the recent floods, multiple risk mitigation and adaptation measures were discussed and implemented, such as: flood barriers, new dikes and extension of existing ones, enlargement of discharging capacity of rivers, retention spaces, emergency plans, public warning and information systems and insurances.

During the consolidation workshop, the following policy questions were elicited as relevant to be analysed with EU-CIRCLE CIRP:

- What are the critical infrastructures in the affected area- which contribute to fast recovery?
- How could impacts develop spatially (e.g. hygienic problems / epidemics as a result of dead animals)?
- What benefit does a new dike/extension of a dike provide?
  - Short term benefits:
    - lowering of evacuation efforts
    - lowering of mobility/transport limitations
  - Long term benefits:
    - agriculture: less pollution with heavy metals
    - faster reconstruction
- Where should emergency resources be placed (power generators, pumps) optimally?
- How many appliances/staff/consumables/vehicles etc. are needed in the future?
- To which extent can intensified cross-border/international help support crises management?
- At which level of the hazard, which area/how many people must be evacuated?
- Where should new settlements/industries be avoided?
- Predict „dimension“ of missions: How many basements must be pumped out?
- Comparisons of strategies: invest in emergency power generators vs. a new dike?
- How can river management / construction be optimized?
- Consider in all analysis different variants: What if:
  - … it rains more frequently/more intensively?
  - … multiple hazards occur simultaneously?

As a time-frame for the analysis, the participants mentioned at minimum 2035. Less than 20 years would mean to react to the current situation but not to the likely upcoming developments due to the climate change. Depending on the type of CI, a time horizon of up to the year 2100 might be appropriate since the normative duration for the use of infrastructure is typically 50 years.

Relevant key words related to resilience raised in the consolidation workshop were: adapt, absorb impact and recover quickly to original state.

The key figures of the two important previous floods in the region of Dresden are the following:

2002 flood event:

- +9.40 meter water level in the Elbe (1/200 per year event), 1000 million euro in damage
- The Weißeritz river, a tributary river to the Elbe, had a 1/500 per year event
- Various measures were taken after this event: floodgates, mobile flood protection, improvement of hydraulic roughness, increasing protection to at least 1/100 per year increasing protection to at least 1/100 per year

2013 flood event:

- +8.77 m water level Elbe (1/50 per year event)

6 Challenges and lessons learned from past cases

Lessons learned from past cases related to the EU-CIRCLE case studies can be summarized as follows:

6.1 Case study 1: Extreme drought and very large forest fires in South France

- Required data include:
- Prolonged and repeated heat waves can lead to large conflagrations due to significant increase of the wind following the dry period
- Fires of large size and extended firefighting operations may lead to loss of multiple assets and subsequent impact due to interconnection and interdependency issues
- Addressing large size fires can't be solved only by resourcefulness since actual weather (wind speed and direction) define the fire potential. Preventive forest fuel management can contribute to fire containment and mitigate the impact
- Loss of one part of the network leads to overloading the normal flow of the remaining network of the essential services
- The main impact of large forest fires to CIs refers to hampering of road traffic (and eventually, depending on the distance, rail and air transport)

6.2 Case study 2: Storm and Sea Surge in the Baltic Sea Port of Gdynia, Poland

Storm surge can cause coastal hydrology changes, flooding, water quality changes, and even inundation of low-lying terrain. Strong wave actions and disruptive winds can damage water infrastructure and other environmental assets (hazardous and solid waste management facilities, wetlands, etc.).

The interactions between wind and baric waves during storm surges allow one to observe that:

- the relative contributions of wind and baric wave to the resultant changes in sea level depend on mesoscale baric lows, their passage velocity and intensity. Deep (< 980 hPa), rapidly moving baric lows cause sea surface deformation mainly as a result of baric wave action. When a baric low system moves at high speed, the wind action in a given direction is limited in duration. The wind energy produces waves and mixes the water, but cannot induce pronounced drifting surges. On the other hand, when baric systems are shallow (> 980 hPa) and slow-moving, the resultant change in the sea level is brought about predominantly by the wind field;
- the type of sea level change (amplitude and timing) is greatly affected by the baric low's trajectory and its distance from the shore. A large positive wave effect occurs when the trajectory is parallel to the coast – in such a case, local conditions play an important part;
- exceptionally severe storm surges occur when the baric wave crest (positive phase) approaching the Polish coast is in harmony with the on-shore direction of the wind.

The sea surface deformation factor by the rapidly moving baric low should be included in future models developed to forecast storm surges and falls.

As regards the relevant issue of sea level rise, the direct and indirect costs of sea level rise for Europe have been modelled for a range of sea level rise scenarios for the 2020s and 2080s [22]. The results show:

1. First, sea-level rise has negative economic effects but these effects are not particularly dramatic. In absolute terms, optimal coastal defence can be extremely costly. However, on an annual basis, and compared to national GDP, these costs are quite small. On a relative basis, the highest value is represented by the 0.2% of GDP in Estonia in 2085.
2. Second, the impact of sea-level rise is not confined to the coastal zone and sea-level rise indeed affects landlocked countries as well. Because of international trade, countries that have relatively small direct impacts of sea-level rise, and even landlocked countries such as Austria, gain in competitiveness.
3. Third, adaptation is crucial to keep the negative impacts of sea-level rise at an acceptable level. This may well imply that some European countries will need to adopt a coastal zone management policy that is more integrated and more forward looking than is currently the case.

For the purposes of EU-CIRCLE, we are mostly concerned with estimates of sea-level rise consequences in the case study area in Poland. Nevertheless, it is worth briefly mentioning that studies undertaken at the regional and local scale suggest that such impacts could be significant. For example, a study of infrastructure in California’s coastal zones (Heberger et al., 2011) [23] details the numbers of schools, wastewater treatment plants, power plant, sites containing hazardous materials and other key facilities that would be at risk were sea-level to rise substantially. This and other regional studies (for example, see Van Koningsveld et al., 2008 [24], for the Netherlands; Breil et al., 2005 [25], for the city of Venice; Smith and Lazo, 2001 [26], summarise many country- and sub-country-level studies from all continents) are suggestive of what the macro-level damages estimated might mean on a micro-scale.

6.3 Case study 3: Coastal flooding across Torbay, UK

Floods may have significant negative impact to critical infrastructures, in particular to transport networks. Such impact is assessed in a report of EEA [27] dated 2014 to be medium by 2025 up to high negative by 2080. The risks envisaged in this report include:

- Damage on infrastructure (e.g. pavements, road washout);
- road submersion;
- scour to structures;
- underpass flooding;
- overstrained drainage systems;
- risk of landslides;
- instability of embankments
- destabilization of rail infrastructure (embankments)
- flood damage to runways and other infrastructure (aviation infrastructure)

- water run-off exceeding the capacity of drainage system

To reduce as far as possible the risk of flooding from sea or extreme rain, Copenhagen Metro has taken this factor into account in the metro's design and construction since the design of the first line in 1993–1995, In fact, the metro has been able to continue operating under the various floods that have hit the city, including the 2011 cloudburst, which stopped rail services, but not the metro. The basis for calculation has been revised, as climate change forecasts have changed over time. For example, the upper limits of all the stairways, emergency exists and ventilation openings on the Copenhagen Metro are now 2.2 m or more above normal sea level around the city for the new lines currently under construction [28].

Figure 18. Flooding gates (design) and sand bags (response) to prevent flooding underground stations

The 17 new metro stations in the Copenhagen area will also be secured against flooding. The construction company has identified how to keep water out of the tunnels in the exposed stations by projecting worst-case scenarios of water levels in the streets around the 17 new metro stations during extreme rainfall. Specific design, like augmenting the entrance above street level by small access ramps or stairs, can prevent great quantities of rain water from running down into the metro. A study on the effects of sea-level rise in Copenhagen and on options for securing the metro against the combined effects of rising sea level and flood waters due to rainfall has been prepared (Fig.18). All new metro stations include access slopes and stairwells 2.42 m above current sea level.

6.4 Case study 4: International Event

In the recent years, most of the coastal cities in Bangladesh got flooded even with a little rainfall of about 20–30 mm and the roads became waterways and collapsed the normal road transportation systems of conventional rickshaws, vans, taxis, cars etc.

During the flood of 2007, Kobadak river had been flowing above the danger level in Jhikargachcha for over 80 continuous days (FFWC, 2007). However, in the other flooded river basins towards the northern reaches, continuous inundation lasted up to 20 days in each of the two flood spells (Ahmed, 2008; Ahmed et al., 2007). Irresponsible shrimp cultivation is also responsible for floods.

Erosion has been becoming a regular natural phenomenon in Bangladesh along the belts of outreach coastal islands like Bhola, Sandwip, Hatia and Kutubdia, which turned massive in the recent years(Rahman, 2010; Miyan, 2012). The major causes of erosion are because the Ganges

Brahamputra Meghna (GBM) river system carries immense volume of water with silt. During the monsoon,GBM system carries about 1.7 billion tons of silt per year causing severe turbulence the rivers. This results in gradual undercutting of riverbanks leading to erosion. During high tide, 30,868 m^3 of sea water flows upward through the cannels of Kutubdia, Sandwip and Hatia. Again, these channels carry down the upstream fresh waters from 38,896 km2 coastal and midland areas of Bangladesh.

Unplanned urbanization, deforestation and hill cutting have created serious land-sliding in Chittagong and Cox's Bazar resulting in the death of hundreds of people. Heavy monsoon rainfall, intensified by strong storms from the Bay of Bengal, caused an abnormal precipitation in the area causing landslides. The combined effect of rainfall and hill cutting induced slope instability and triggered landslides in Chittagong. The combined effect of hill cutting and climatic change have induced erratic behavior of the nature causing tragic deaths in 2000, 2007, 2008, 2012 and 2013 (Sarwar, 2008; Rahman, 2013; Dhaka Tribune, 2013).

6.5 Case 5: Rapid winter ice melting and river floods around Dresden, Germany

- Required data include:
    - Environmental data including DTM, land-use, hydrographic network, water levels for rivers, warning levels
    - Critical Infrastructure data i.e. transport, energy, water network, settlements boundaries, emergency services data (rescue and fire stations, police, medical, disaster relief, public shelters, depots..),
- Additional info including hydrographs data, (blocked) rain/storm drains, low lying areas maps and basements
- Flooded area map layers (flood extent, water height and speed) for different water levels. The current rate of flooding the area in order to be compared with climate change driven flood events due to rapid ice melting. This is linked with the snow melt rate, the snow coverage of the basin, the snowpack density, the snow height at melting start, the river drainage area, the snow cover etc (evaporation can be neglected for simplification). Such layers may be available in advance for (pre-) generating flood maps to be used as input to CIRP.
- Wet days combined with soil water capacity (linked to water table depth) during (rapid) snow melt can define the occurrence and
- Required spatial resolution from 1 to few kilometres (?)
- Climate drivers to be considered are: Number of consecutive wet days, amount of precipitation, duration, rainfall intensity (rain quantity/time), stormicity etc
- Main infrastructure that will be considered in this study case is transportation
- The autonomy of operation of the critical infrastructure assets (e.g. power supplies) has to be treated as retrofit (modification) measure linked to the relative damage curve and associated with the envisaged asset.

7 Future aspects on using EU-CIRCLE (the way ahead)

EU-CIRCLE delivers a methodological framework for addressing issues related to assessing the risk of critical infrastructures due to climate change potential and examine adaptation options that may ensure its resilient operation. This methodological framework is supported by CIRP, a software platform which enables the modelling and analysis of critical infrastructure network aiming to allow national and regional authorities to document their plans for addressing climate change related risks and strengthen resilience.

The project has selected a number of diverse use cases for the proof of concept of the EU-CIRCLE methodology and the evaluation of the relative tools that are currently under development. Representative disruptive scenarios are used for organizing the involvement of proper stakeholders and validating the contribution of the project and the CIRP tools towards the objective of improving resilience planning in context of the climate change. This part of the document provide alternative cases for the scenarios that will be used and aims to feed relative discussions in context of the detailed planning of the EU-CIRCLE demonstrations.

7.1 Case study 1: Extreme drought and very large forest fires in South France

Within planning of Case Study 1, impacts of forest fires to critical infrastructure and relative essential services may consider among others the following:

- To get EU-CIRCLE under way, stakeholders representing Government (Local, Regional or National), Public services (LEAs, Civil Protection, Emergency, Health), Meteo services, Hazard and risk modelers, CIP authorities, CI operators and owners have to be involved
- The EU-CIRCLE platform can be used to identify high fire risk areas and periods in regions of interest within the next decades, based on data provided by regional climate change models. The presence and resiliency of the CIs within such areas should be supported by CIRP. Examining the response of the assets at risk against the intensity of the fire (damage or consequence curve) we may have a measure of the expected damage and using CIRP capabilities it will be possible to assess the impact of such damage to the performance of the essential service and its interconnected and interdependent infrastructures.
- Larger than today and more intense forest fires may have significant spatial dimensions increasing greatly the CI assets at risk and the probability of experiencing negative consequences if proper adaptation measures won’t be taken. Fire behaviour models and simulators of fire propagation may support such tasks and create input layers for the CIRP platform.
- Forest fire risk zoning can be redefined at the national and EU level, using assessments and data input of the regional climate change models. A priori application of fire risk indices [37] using IPCC climate data sets for the area of interest can be used for this purpose providing input layers to EU-CIRCLE. This will improve mitigation planning at the regional, national and EU level as regards the intrinsic forest fire danger (climate and vegetation response to fires)
- Impact of very large forest fires to CIs is mainly related to consequences to road transport, power grid network, telecoms and health services.

- For the impact of forest fire to the road transport the efficiency of each road network link should be estimated and then compute the importance of each network component. Thus a criticality index for each link represents the difference of the network's efficiency after the link(s) removal in relation to the initial (normal) condition of the network. This exercise has to be conducted at the local level of the road network, in order to determine the impact of the closed (removed) links and their effect on the overall traffic circulation. The higher the efficiency values of the closed link, the more severe the effect it has on the network. A similar analysis has to be conducted for the national road network of the study area, in an effort to identify the importance of each link and the extent to which the network would be affected, had it been closed due to extreme circumstances. Such analyses are important at a planning level, as they provide authorities with a tool that identifies the network components (road links) whose operation has to remain uninfluenced, especially in cases of extreme weather events [38].
- Smoke plume dispersion modelling, such as the VSMOKE [39], CONUS [40], HYSPLIT [41]or web services like BLUE-SKY [42] can be used in combination with visibility damage curves for creating relative input layers for CIRP.
- Addressing cross-border road transport planning issues
- Multimodal transport to resolve traffic flow issues
- Public health system should be adapted to the estimated frequency of forest fires and the consequences of the related emissions

7.2 Case study 2: Storm and Sea Surge in the Baltic Sea Port of Gdynia, Poland

Currently in case study 2, risk assessment and impact of climate change due to worsening of the regime of storm and sea surges in the Baltic sea and specifically in the port of Gdynia, focusing to the case of oil transport and loading. Therefore eventual consequences to the loading system and the pipeline infrastructure will be considered. Impact to the operations linked with the oil supply chain can be further considered using the EU-CIRCLE outcome.

The impact of the storm and sea surges to the port operations and their consequences to the oil transport and oil loading operations can be addressed in the future based on the results of the project.

7.3 Case study 3: Coastal flooding across Torbay, UK

Multiple approaches for improved mitigation are in the discussion, among them:

The identification of Torbay as a critical drainage area

- Control of development within Torbay
- Sustainable drainage considered first
- Only if sustainable drainage is not viable and/or limits discharge to a watercourse, main river or sewer be considered. The discharge will be limited to the 10year greenfield run off rate for the development site.

- By implementing this control on development it will be possible to reduce flood risk

Coastal defence study

- Assess current performance criteria
- Assess future requirements for 20 years,50 years and 100 years of sea level rise

Flood alleviation schemes

- Reduce impact of climate change and resolve historic flooding problems

Local flood warnings

- Network of rain gauges and depth gauges providing automated alarms for local community
- Infoworks ICM Live hydraulic modeling could be used to provide a fast, accurate forecast of flood risk at property level. This tool can be used to provide alarms for preset flood warning triggers. Simulations would be re-run based on rainfall forecasts at between 60 and 15 minute intervals depending on the intensity of the rainfall forecast. Accuracy of this modeling can be improved using the ―hindcast period.

In the course of EU-CIRCLE case study 3, effects of climate change will be further elaborated:

Rising sea level

- Increased risk of overtopping
- Restricting outfall discharges

More intense rainfall

- Increased surface runoff
- Increasing risk of localised flooding
- Reduced hydraulic capacity of drainage systems The following outcomes are expected from the case study:
- Identify infrastructure at risk due to climate change
- Identify future mitigation works
- Produce a plan to allow resilient development

During the consolidation workshop discussion took place with regards to the time horizon that should be used during the case study and it was agreed that three time periods should be considered in order to be adaptive. These were 20years, 50 years and 100 years.

Relevant key words/phrases related to resilience raised in the consolidation workshop were: interaction of all sources of flooding, risk acceptance criteria and building the capacity.

7.4 Case study 4: International Event

Climate change in Bangladesh is expected to increase the intensity of cyclones, resulting in the penetration of storm surges further inland, causing higher damages. According to the Center for Global Development Working Paper 182 (Dasgupta et al., 2009) [43], intensified storm surges due to SLR and ice melting will create more damaging flood conditions and inundations of the coastal cities.

7.5 Case 5: Rapid winter ice melting floods around Dresden, Germany

- Identification of cases (time periods and areas) shifting from Long Lang Times to Short Lag Times of a river discharge

During the consolidation workshop, the following policy questions were elicited as relevant to be analysed with EU-CIRCLE CIRP:

- What are the critical infrastructures in the affected area- which contribute to fast recovery?
- How could impacts develop spatially (e.g. hygienic problems / epidemics as a result of dead animals)?
- What benefit does a new dike/extension of a dike provide?
- Short term benefits:
- lowering of evacuation efforts
- lowering of mobility/transport limitations
- Long term benefits:
- agriculture: less pollution with heavy metals
- faster reconstruction
- Where should emergency resources be placed (powergens, pumps) optimally?
- How many appliances/staff/consumables/vehicles etc. are needed in the future?
- How can cross-border/international help support crises management?
- At which level of the hazard, which area/how many people must be evacuated?
- Where should new settlements/industries be avoided?
- Predict „dimension― of missions: How many basements must be pumped out?
- Comparisons of strategies: invest in emergency power generators vs. a new dike?
- How can river management / construction be optimized?
- Consider in all analysis different variants: What if:
- … it rains more frequently/more intensively?
- … multiple hazards occur simultaneously?
- As a time-frame for the analysis, the participants mentioned at minimum 2035. Less then 20 years would mean to react to the current situation but not to the likely upcoming developments due to the climate change. Depending on the type of CI, a time horizon of up to the year 2100 might be appropriate since the normative duration for the use of infrastructure is typically 50 years.

- Relevant key words related to resilience raised in the consolidation workshop were: adapt, absorb impact and recover quickly to original state.

8 Options of EU-CIRCLE use in context of the case studies

According to the DoW (D3.4), the following strategy is considered by the consortium in order to conduct the case studies with reference to the proposed risk assessment modelling framework [44].

1) Setup – scenario specification design. This task will result in an initial scenario specification which will guide the initial stages of the case study in the quest for the most suitable models and fitting climate / weather data and CI asset definition.
2) Model implementation and customization, will result in a very specific elaboration of the web-based tool using CI models, systems and climate / weather data required to perform each case study.
3) Case Study Description and preparation, where a specific scenario will be derived, with discrete events and their timeline, CI description, targets and envisaged application of the EU-CICLE framework. During the course of the actual demonstration different variations of the case study may be demonstrated, for example different climate hazards, timescales introduced, adaptation measures and their comparison and validation etc.
4) Data collection. This task involves the collection and processing according to the EU- CIRCLE defined standards of the necessary data in order to conduct the case study. This task will involve particularly CI assets / networks and auxiliary data (e.g. population, land use / land cover, socio-economic, adaptation technologies costs) which are required in order to smoothly execute the envisaged case study.
5) National training course (1 day before case study). Participants to the case study will be have the opportunity to familiarize themselves with the EU-CRICLE web-based tool and holistic resilience framework.
6) Execution of the case study, conducted for 1 day at the local organization premises, with active participation of local End Users and CI stakeholders
7) Validation by End Users. In the last part of the case study day, the participants will provide an independent evaluation of the EU-CIRCLE, according to the validation framework analysed in Task 6.1
8) Summary Report of each case study including all the activities and external experts responses.

The above approach [45] combined with the methodological framework of EU-CIRCLE [46] and the use of the CIRP tools can be implemented to the project case studies according to the following:

1. CI network information definition

   a. We have the network of the CIs assets (nodes, links) and their associated attributes inserted in CIRP

   b. Authorities and operators can use the authoring tool of CIRP to select *specific* network elements (assets), display and edit the values of their attributes (related to risk, impact, resilience). Furthermore they should have the possibility to insert new attributes in the asset's table (attribute will be associated with all assets of this type)

   c. Using the authoring tool the end user (operator, authorities) should be able to define/edit interconnection and interdependency information since it will support the evaluation of "what-if" solutions (otherwise a methodology how this should be done outside CIRP has to be defined)

2. Climate and Climate change data management

   a. The end user has to input the area of interest (e.g. providing the coordinates of the bounding box or just selecting among the case study areas of EU-CIRCLE) and the envisaged time period (e.g. 2016-2066)

   b. The end user has to select if he/she is interested for:

      i. specific climate drivers (meteorological parameters available and stored in the IPCC GM data sets). These data can be downloaded from existing repositories or EU-CIRCLE data bases created for the project case studies and/or

      ii. specific climate hazards (e.g. floods, forest fires etc). These should be prompt layers (a hazard layers data base) produced based on request of the end users by external hazard modelling services

   c. The CIRP should provide the users with the capability to download and store (bi) data and/or insert in to the platform (bii) layers)

   d. CIRP should provide users with data filters and processing capability in order to assess and visualize climate threat scenario (e.g. areas of values exceeding thresholds for a certain time duration) or identify worst case scenario (e.g. highest precipitation percentile within a 100y period).

   e. CIRP should provide the capability to insert, display and overlay CI layers (1) with the selected hazard layers (bii)

3. Definition of the Climate and Critical infrastructure interaction

a. The user has to select the CI network (as defined in 1) and the climate scenario (as defined in 2) that will be used later in the resilience analyses

b. Using the authoring tool and the respective editor the users should be able to set/view/edit/modify relevant damage funtions[1]. Damage functions should be related to specific resilience thresholds (downtime, restoration time, demand coverage etc). This can be done using an adequate tabular or graphical editor

c. The end users should be able to define resilience thresholds for specific assets using an appropriate editor. Each damage function (curve) has to be linked with a respective resilience threshold

4. CIRP analysis of CIs resilience to climate-driven threats

    a. Based on the input data mentioned above (area, time period, CI assets, climate threats, hazards, damage functions ..) CIRP should apply the EU-CIRCLE risk assessment methodology in order to show risk level of climate threats and hazards to the respective CIs. This can be linked to the likelihood of threat/hazard presence (related to the analysis of climate and environmental data) in the case study area, the exposure of the CI assets (using spatial analysis with The GIS capabilities of CIRP) and the vulnerability of the assets to the specific threat/hazard (using the properly defined damage functions)

    b. The users can use CIRP to visualize results to a single CI network (e.g. identify potentially failed nodes/links)

    c. Identify among the potentially failed nodes of 4b those that that are interconnected or interdependent with other CIs, which thus shall transfer their consequences to other nodes and networks

    d. Run repeatedly the single CI network (alternative) solutions and calculate the final network performance levels or challenges till successful failure

    e. Run multiple network layers option (interconnections and interdependencies to be considered) to calculate the optimal performance levels of the CI networks net in order to comply with resilience objectives

5. Considering resilience/adaptation options

    a. Societal and economic aspects of the network analyses have to be provided to the users by comparing network solutions and resilience thresholds

[1] A damage function or damage curve define the relation between values of an attribute of a CI asset and a climate or hazard parameter

b. The users should be able to identify points of failure along the analyses of 4 and to test solutions by changing input data.

 i. They have to be able to change the damage functions (this would correspond to retrofitting the asset)

 ii. Modify the network configuration (changing the location of an asset or changing interconnection and interdependency relations)

A network optimizer that could recommend sustainable network solutions, within a predefined range of states, to achieve specific resilience objectives could be an advanced option of CIRP.

Here next the above approach is roughly adapted to the specific case studies of EU-CIRCLE

8.1 Extreme drought and very large forest fires in South France

The forest fire case study of EU-CIRCLE (Fig. 19) will be applied in South France and will be based on a scenario as follows:

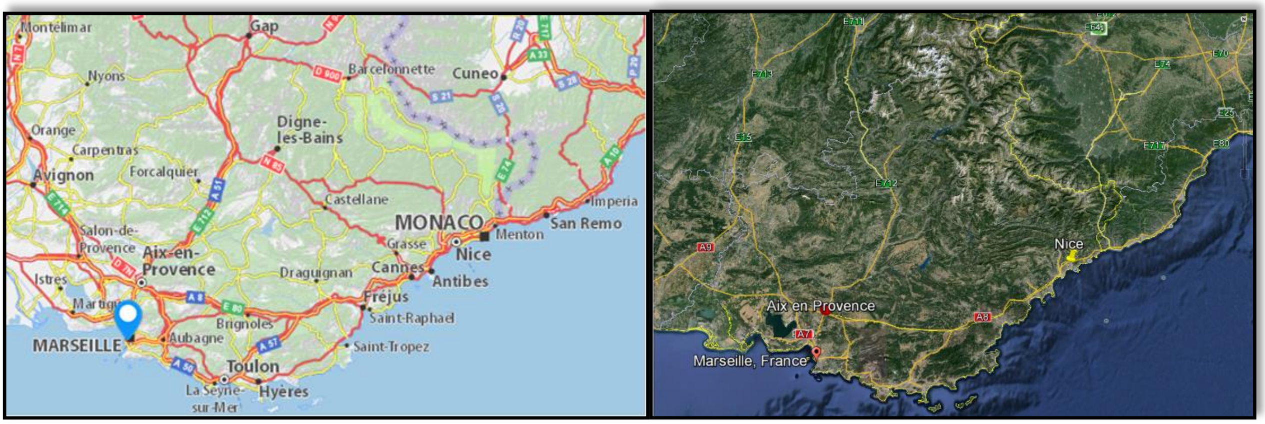

Figure 19. Map of the area of the wildfire study case of EU-CIRCLE in the French-Italian borders

In mid-August“2033”, following a severe period of dryness with no significant rain for months, simultaneous forest fires ignite in the Bouche du Rhone department near Aix en Provence, and in the Alpes Maritimes Department, close to the French/Italian borders and near highway A8, which is used by thousands of tourists.

Due to significant quantities of smoke released by the fire, the visibility in the area is strongly reduced so that the road (highway) operator decides to close the road for security reasons. This lead to traffic blockages and aggravation in the secondary road network. Several cars of tourists are jammed in the crossing points of the Franco-Italian borders in Menton and Ventimiglia, which close temporarily and borders crossing is diverted to Olivetta San Michele. Many tourists remain stalled on highway rest areas. People, blocked on the roads, not far from the active fire front start having breathing problems because of the dense smoke and some of them leave their cars in panic, scattering into the nature. Additional road accidents are caused due to low visibility, traffic conditions and because of the panic of people.

Due to aerial firefighting, utilities have to shut down power lines as a safety precaution.

Due to the dispersion of the fire plume, aerial traffic in Nice airport has to be stopped.

Numerous customers and households remain without electricity and of course without telephones.

Emergency operations are disturbed because of the large delay of alert, major dispersion of means, decrease of available means.

The scenario poses the issues shown in Table 4:

Table 4. CIs involved in study case 1 and potential impacts[2]

		Critical infrastructure impacts				
Cause and response	Impact driver	Transportation	Energy	Telecom	Health	Emergency services
Large scale forest fire	smoke, fire, panic	Low visibility, fallen tree blockage	Controlled outage, transformer fire, poles burning	Network overload/failure, trunk network node fire	Respiratory problems, intoxication, burnings, fatal injuries	Scarce resources
Firefighting	Increased use of firefigthing means (trucks, ambulances, water carriers..)	Priority, low speed ..			Injured firemen	
Aerial Firefighting	Water bombing		Power lines cut-off, Brown-outs	Telecomunication links lost		
Evacuation	Mass movement	Traffic overload, jams				
Road closure, low border point closure, airport closure	loss of nodes and links of CI networks	Traffic overload, jams				
International cooperation	standards, language, cross-border agreements					

Here next is provided the context of implementing the EU-CIRCLE methodological framework by potential end users (CIP owners, operators, public authorities and Emergency services) using relative CIRP tools as regards the Case 1:

1. CI network information definition and management

[2] These tables can be filled further and used in context of the planning of the EU-CIRCLE trials related to the study cases

a. Transport, Energy, Telecommunications, Health and Emergency services network of assets is created and inserted in CIRP

b. Values of the attributes of the networks of 1a are edited/modified by the CIRP users to adapt values according to the scenario data

c. End users edit/modify interconnection/interdependency options according to the envisaged situation in the scenario

2. Climate and Climate change data management

    a. The end user input a certain time period (e.g. 2016-2046) and they download selected (in step 2.c) and available (global or climate) data for the Case 1 area and for the specific time period. These data can be downloaded from EU-CIRCLE data bases created for the project case studies.

    b. The end user may select the relative climate data i.e.:

        i. specific climate driver (e.g. drought: layer of areas >60 days without rain maybe combined with a layer of temperatures >30^{o} C)

        ii. specific climate hazards (e.g. fire: layer of weather fire index).

    These should be prompt layers (a hazard layers data base) produced based on request of the end users by external hazard modelling services

    c. The CIRP allows users to download and store the (bi) data and/or insert them in to the platform (bii) layers

    d. Users select and display (using CIRP filters) layers of:

        i. dry areas of case study 1 with prolonged drought season (e.g. >60 dry days) for the period 2020-2030 or 2030-2035 or

        ii. classified drought period duration (e.g. 45, 60, >60 days since rain) or

        iii. areas with (absolute) longer dry season within a long time planning period (e.g. 50 years or more)

    e. Users insert, display and overlay CI layers (of step 1) with the layers of step d.

3. Definition of the Climate and Critical infrastructure interaction

    a. The user select from the CI networks defined in step 1 and the climate scenario defined in step 2 to be used later in the resilience analyses

   b. Using the authoring CIRP tool and the respective editor the users should be able to set/view/edit/modify the relevant damage functions. Damage functions should be related to criticality of the asset and the specific resilience thresholds, defined by the user (3c), according to the type of the CI (downtime, restoration time, demand coverage etc.). This can be done using an adequate tabular or graphical editor. In relation to forest fires, fire line intensity and smoke are the threats that can damage the service level of the CIs involved in study case 1. The length of the drought period is also a factor to be considered in the damage function of some CIs.

   c. The end users define, using an appropriate CIRP editor, the thresholds resilience of the resilience indicators for the specific assets of the CI network. Each damage function (curve) has to link a specific damage factor (e.g. fire line intensity, smoke) with a respective service indicator and its resilience threshold.

4. CIRP analysis of CIs resilience to forest fire related climate threats

   a. Based on the input data mentioned above (area, time period, CI assets, drought, fire weather index, damage functions ..) CIRP apply the EU-CIRCLE risk assessment methodology and display to the end user the risk level of drought and fire danger related to the respective assets of the CIs. This can be linked to the likelihood of forest fire (fire weather index) in the case study area, the exposure of the CI assets (using spatial analysis with the GIS capabilities of CIRP) and the vulnerability of these assets to forest fire (using the properly defined damage functions in step 3 above)

   b. The users can use CIRP to visualize results concerning a single CI network (e.g. identify potentially failed nodes/links due to fire line intensity or to smoke)

   c. Identify among the potentially failed nodes of 4b those that are interconnected or interdependent with other CIs, which thus shall transfer their consequences to other nodes and networks

   d. Run repeatedly the single CI network (alternative) solutions and calculate the final network performance levels or challenges till failure

   e. Run multiple network layers option (interconnections and interdependencies to be considered) to calculate the optimal performance levels of the CI networks net in order to comply with the set resilience objectives (indicators' thresholds).

5. Considering resilience/adaptation options

   a. Societal and economic impacts of large fire occurrence have to be assessed through I/O and network analysis and be compared using CIRP capability with the respective user-defined requirements (expressed as relevant resilience thresholds) for the (wider) case study area

b. The users should be able to identify points of failure across the analyses of step 4 and test alternative solutions by changing (editing) input data.

   i. They have to be able to change the damage functions (this would correspond to retrofitting the asset)

   ii. Modify the network configuration (changing the location of an asset or changing interconnection and interdependency relations)

8.2 Case study 2: Storm and Sea Surge in the Baltic Sea Port of Gdynia, Poland

The use of EU-CIRCLE development, in context of Case study 2, would be related to the two planned scenarios i.e. a. Oil transport in Port and b. Chemical spill due to Extreme Sea Surges. The resilience management should be related to the risks related with sea level rise, storm surges, extreme wind and wave profiles and the impact that they may have to the port infrastructure related with oil transport and storage.

The scenario poses the issues shown in Table 5:

Table 5. CIs involved in study case 2 and potential impacts[3]

		Critical infrastructure impacts				
Cause and response	Impact driver	Cargo vessel	Port oil transportation (under sea)	Port oil transportation land	Port wharves	Coastal area
Sea level rise	Extreme sea surges					
Storm surge	- Rain - High winds - Floods - Tidal change	- Collision - Allision - Grounding - Increased corrosion in metals due to increased sea spray	- Deterioration of pipeline quality due to increased corrosion	Deterioration of pipeline quality due to increased humidity and salinity of sea water	- Affects the future design and operation of near shore and shore infrastructures - Increased force exerted on docks - flooding of marine infrastructure - physical damage to the port infrastructure that can then lead to a catastrophic event - Combined with strong winds, storm surges could cause significant	- More extensive coastal inundation

[3] These tables can be filled further and used in context of the planning of the EU-CIRCLE trials related to the study cases

					increase in sea level and increased flood risk - Wharves to be rebuilt, moved or raised to avoid inundation - Increased risk of basement and localized flooding - Problems to drainage system	
Wave profiles		Cargo ship unable to access berth				
Stop fueling	High wind speeds (Cranes stop work at 70km/hr, Straddles stop work at 90km/hr)					
Chemical spill		- technical failure and defects of equipment such as oil loader at a barge and truck loading terminal that can cause oil to spill				- Coastal pollution
Port closure						

8.3 Case study 3: Coastal flooding across Torbay, UK

As sea level rise is predicted to rise in the Torbay area over 1 m in the next 100 years, both: frequency and impact of overtopping will increase resulting in more infrastructure and properties being affected by flooding. Also, more intense rainfall causes more surface runoff increasing localised flooding and erosion. Existing drainage systems already have hydraulic capacity issues and therefore more intense rainfall will increase the flood risk from these systems.

An indicative option of a relevant scenario for study case 3 is the following:

During a severe storm the sea wall at Livermead in Torquay is breached. As a result of this breach, the main highway linking Torquay to Paignton has to be closed to traffic and the sewage system that transfers all of Torquay's sewage to the sewage treatment works fails. Also, a high pressure gas main is damaged. This may require that all residents and businesses within a larger radius would have had to be evacuated. The situation gets worst due to overtopping of the sea walls and extra flooding of the main coast road linking Torquay to Paignton and Brixham. Numerous roads in Torbay are blocked by waters and since Torbay relies on tourism for its economy, the flooding incident has very significant economic impact.

The scenario poses the issues shown in Table 6:

Table 6. CIs involved in study case 3 and potential impacts[4]

		Critical infrastructure impacts				
Cause and response	Impact driver	Transportation	Energy (Gas)	Telecom	Health	Emergency services
Coastal flood	Water depth and extent, runoff, duration	Non accessible roads, Blocked roads, rails	Gas main operation fails	Network overload/failure	Injuries, Infection diseases	Blocked resources, scarce resources
Overtopping of sea wall	Water depth	Flooded coastal road, sea port damages			Injured people	
Breaching of sea wall	Water depth	Safety of people traveling close behind the defence structure				
Evacuation	Number of people	Traffic overload, jams in flooded roads	Clear the area in the proximity of gas main	Network overload/failure		Apply evacuation plan, additional resources
Pumping water	Quantity of water	Unblock critical road transport assets				
Sewage system failure	Runoff, duration					

Here next is provided the context of implementing the EU-CIRCLE methodological framework by potential end users (CIP owners/operators, local public administration, CIP authorities and Emergency services) using relative CIRP tools as regards a scenario for Case 2:

1. CI network information definition and management

[4] These tables can be filled further and used in context of the planning of the EU-CIRCLE trials related to the study cases

a. Transport, Energy, Health, Telecommunications and Emergency services network of assets is created and inserted in CIRP

b. Values of the attributes of the networks of 1a are edited/modified by the CIRP users to adapt values according to the scenario data

c. Sea flood defence infrastructure assets are also inserted in CIRP (as a protection/coping capacity layer)

d. End users edit/modify interconnection/interdependency options of the CI and protection layers according to the envisaged scenario

2. Climate and Climate change data management

a. The end user input a certain time period (e.g. 2016-2046) which is used to download selected (in step 2.c) and available (global or climate) data for the study case 2 area and for the specific time period. These data will be downloaded from EU-CIRCLE data bases created for the project case studies.

b. The end user may select the relative climate data to download from the EU-CIRCLE data bases i.e.:

i. specific climate driver (e.g. sea level rise exceeding 0,5m or 0,7m ..)

ii. specific climate hazards (e.g. flood: water depth, runoff speed etc.).

The latter should be prompt layers (a hazard layers data base) produced based on request of the end users by external hazard modelling services

c. The CIRP allows users to download and store the (bi) data and/or insert them in to the platform (bii) layers

d. Users select and display (using CIRP filters) layers of:

i. Potentially flooded coastal areas for a period e.g. 2020-2070 corresponding to sea level rise of 0,70m or

ii. Potentially flooded internal areas due to overtopping of sea walls within a period e.g. 2020-2070 with water depth above 0,6m etc.

e. Users insert, display and overlay CI layers (of step 1) with the layers of step 2.

3. Definition of the Climate and Critical infrastructure interaction

a. The user select from the CI networks defined in step 1 and the climate scenario defined in step 2 those to be used later in the resilience analyses

b. Using the authoring CIRP tool and the respective editor the users should be able to set/view/edit/modify the relevant damage functions. Damage functions should be related to criticality of the asset and the specific resilience thresholds, defined by the user (3c), according to the type of the CI (downtime, restoration time, demand coverage etc.). This can be done using an adequate CIRP tabular or graphical editor. In relation to coastal floods, the flood water depth, the speed of runoff and the residence time of flooded water can be considered among the threats that can damage the service level of the CIs involved in study case 2.

c. The end users define, using an appropriate CIRP editor, the thresholds resilience of the resilience indicators for the specific assets of the CI network. Each damage function (curve) has to link a specific damage factor (e.g. water depth) with a respective service indicator (road availability) and its resilience indicator (e.g. time to restore) threshold.

4. CIRP analysis of CIs resilience to coastal flood related climate threats

   a. Based on the input data mentioned above (area, time period, CI assets, flood extent, CI exposure, flood characteristics, protection measures, damage functions ..) CIRP apply the EU-CIRCLE risk assessment methodology and display to the end user the risk level of flooding of the area related to the respective assets of the CIs. This can be linked to the likelihood of flood in the case study area using flood modelling input from external models or services, the exposure of the CI assets (using spatial analysis with the GIS capabilities of CIRP) and the vulnerability of these assets to flooding (using the properly defined damage functions in step 3 above)

   b. The users can use CIRP to visualize results concerning a single CI network (e.g. identify potentially failed nodes/links due to flood water depth)

   c. Identify among the potentially failed nodes of 4b those that are interconnected or interdependent with other CIs, which thus shall transfer their consequences to other nodes and networks

   d. Run repeatedly the single CI network (alternative) solutions and calculate the final network performance levels or challenges till failure

   e. Run multiple network layers option (interconnections and interdependencies to be considered) to calculate the optimal performance levels of the CI networks net in order to comply with the set resilience objectives (indicators' thresholds).

5. Considering resilience/adaptation options

a. Societal and economic (touristic indices) impacts of coastal flood occurrence have to be assessed through I/O and network analysis and be compared using CIRP capability with the respective user-defined requirements (expressed as relevant resilience thresholds) for the case study area

b. The users should be able to identify points of failure across the analyses of step 4 and test alternative solutions by changing (editing) input data.

    i. They have to be able to change the damage functions (this would correspond to retrofitting the asset)

    ii. Modify the network configuration (changing the location of assets or changing interconnection and interdependency relations among them)

8.4 Case study 4: International Event

The main focus of the critical infrastructure impacts will be concentrated within the **Khulna district** on the effect on **roads** and **water infrastructure** (most parts of the district do not have electricity, hence will not be a sector that will be considered under infrastructure), which are key to the survival and sustainability of the community. The area that is affected consists of agricultural land and is highly connected to the livelihoods of the people. Hence roads and water infrastructure is importantly linked to the livelihoods of people. Damage data is scatted. Some are at national lead institutes (eg. roads- Local Government Engineering Department (LGED)). The socio-economic data is collected via local government organizations. Discussions with our Bangladesh partners will enable us to determine the area of the case study impact. One of the challenges in linking the socio-economic data to the impact of Cyclone Aila is the regular occurrence of flood events in the country and linking the specific flood event to the socio-economic impact due to the event will be challenging as data is scattered and there are difficulties in linking the data that is available to the specific cyclonic event. This will be discussed further with the local stakehoders within the international case study when it commences.

The broad policy making question addressed within the case study from an EU-CIRCLE perspective is ―to provide a validated framework supported by CIRP to enhance cooperation with relevant third countries, regions and international organisations to exchange practices and concepts‖. CIRP will be a collaborative environment nurturing scientific and operational collaboration, thus significantly enhancing the uptake of high quality research by the relevant stakeholders with customizable outputs to be produced by CIRP.

8.5 Case 5: Rapid winter ice melting floods around Dresden, Germany

The flood scenario of case study 5 shall test EU-CIRCLE development concerning relative risks and resilience of critical infrastructure mostly related to the transport sector. As for all case-studies of EU-CIRCLE, several options of using the project development to identify impacts of climate change risks (flood in this case) and support relevant adaptation options based on resilience indicators may be analyzed using the project tools and methods. The impact of changing frequency of rain floods, the amount of snow stocked during snowfall and the respective rate of melting of snow/ice shall be considered.

The scenario of Case 5 may pose the issues shown in Table 7:

Table 7. CIs involved in study case 5 and potential impacts[5]

		Critical infrastructure impacts				
Cause and response	**Impact driver**	**Transportation**	**Energy**	**Telecom**	**Health**	**Emergency services**
River flood	Water depth and extent, runoff, duration	Non accessible roads, Blocked roads, rails	Gas main operation fails	Network overload/failure	Injuries, Infection diseases	Blocked resources, scarce resources
Snowfall	Snow height	Flooded coastal road, sea port damages	Increased demand, icing of exposed components, blackouts	Network failures	Injured people, fractures	
Ice/Snow melting	Water rise speed	Safety of people traveling, Blocked roads, rails				
Evacuation	Number of people	Traffic overload, jams in flooded roads	Clear the area in the proximity of gas main	Network overload/failure		Apply evacuation plan, additional resources
Pumping water	Quantity of water	Unblock critical road transport assets				
Sewage system failure	Runoff, duration				Infection diseases	

[5] These tables can be filled further and used in context of the planning of the EU-CIRCLE trials related to the study cases

9 EU-CIRCLE operational aspects

The above scenario can be considered as a representative climate change use case for a table top exercise aiming to assess the performance level and the resilience of the critical infrastructures (assets and network) in a specific region in case of a very large forest fire or the occurrence of multiple fires in parallel in the same region, which shall potentially merge leading to the same result i.e. a very large forest fire or a mega-fire.

9.1 Stakeholders feedback

Based on the feedback received from stakeholders in context of focused project meetings, the EU-CIRCLE outcome could become operable following the five methodological steps shown in the Figure 20. It has to be noticed that currently the interest is rather associated to national and EU authorities and CIP initiatives. The CI owners, managers and operators are interested for the daily operations of their facilities, while the security liaison people of the critical infrastructures also focus to risk management rather than to the resilience-based planning and especially linked to climate change. This is considered reasonable for a number of reasons such as the very-long term of climate change impacts, the complexity of the interdependencies among CIs and the uncertainties associated with the vulnerabilities of the CI elements, combined with the unpredictability of climate extremes.

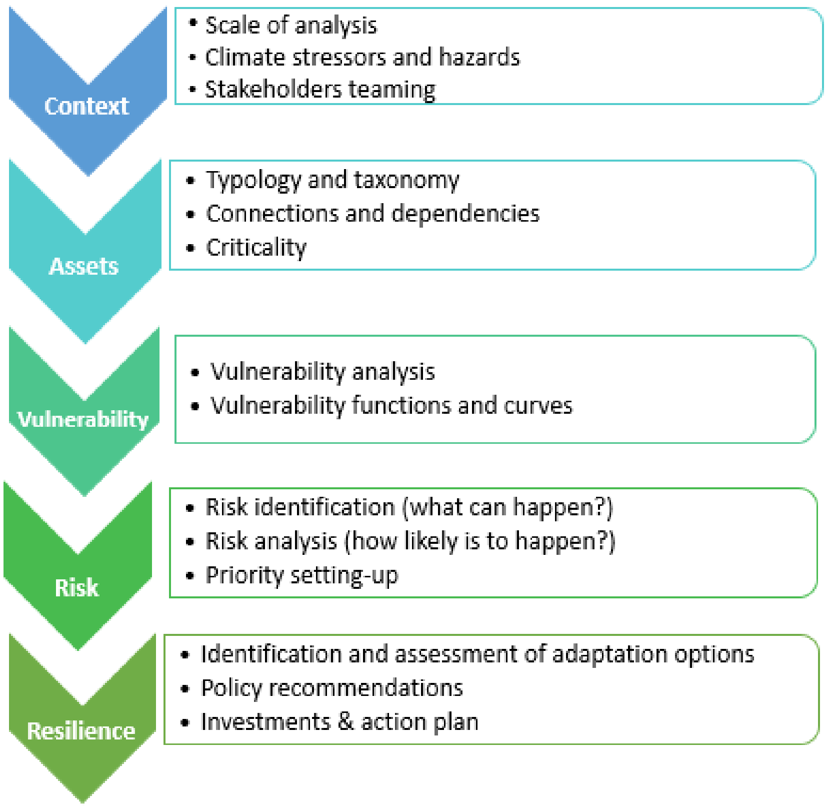

Figure 20. Procedural steps of EU-CIRCLE methodological framework

Furthermore, resilience and adaptation include social dimensions that can often be in conflict with strict economic and business interests.

It was made evident that a significant obstacle for implementing the EU-CIRCLE methodology is the required trust among the stakeholders of the CI resilience. The involvement of CI operators and national authorities in joint groups can support trust building between the government and civil society while it can also lead to informed decision making. In context of the project methodological framework consensus among stakeholders at early stages can reduce the likelihood of conflicts.

In order to integrate smoothly the disaster risk management with resilience and adaptation issues, EU-CIRCLE aims to provide CI stakeholders with capabilities to:

- reduce the likelihood and probability of damage and failures to critical infrastructure
- reduce the consequences from climate related failures and;
- reduce the time to recovery back to normality

A major issue for implementing the EU-CIRCLE methodological framework is to ensure interaction between all the involved CI stakeholders with the climatology and the risk and hazard modelling community. Furthermore the issue of infrastructures resiliency and the adaptation planning for addressing climate change impacts would be supported by the national and EU authorities, which seems to be the more relevant end users of the EU-CIRCLE results. The community of the CI operators might be interested to follow and endorse guidelines and directives that would be based on a resilience framework that could integrate the consequences of the climate impact in a clear and comprehensive manner.

10 Conclusions

This document is a complement of the deliverable D1.4, which introduced a comprehensive methodological approach for assessing the resilience of Critical Infrastructure and essential services to emerging challenges related to climate change.

In this report, beyond the high level methodological framework defined in D1.4, options and suggestions that can support the organization and planning of the EU-CIRCLE study case trials are provided. Based on stakeholders input to overcome problems linked with the lack of vulnerability curves (or damage functions), which are used to relate critical assets with climate stressors it is proposed the development of relevant editors that may grasp the relative expertise and experience of CI operators and security managers.

A significant capability that EU-CIRCLE can provide to the project stakeholders, making sense for their familiarization with resilience as well as to the opportunities they may have to improve the protection of their facilities is the organization, access to time-series of climate-change data for a specific region. This ability can make CIRP valuable for all types of stakeholders being them CI operators, civil protection actors, law enforcement agencies, public administration or even researchers of CIP.

The methodological framework indicates a procedural context for organizing a cooperation between stakeholders including climatologists, modelers, critical infrastructure operators, national and EU CIP authorities and regional government or administration. The planned tools of EU-CIRCLE shall support resilience management of critical infrastructures at the individual element as well as at the network level. This report provides also numerous ideas concerning the capabilities, the functionality and the operational properties of the CIRP toolbox of EU-CIRCLE.

Beyond the assessment of robustness of the critical infrastructure against the extreme climate events associated to the climate change, this report notices the need of EU-CIRCLE to consider the impact of climate change, expressed as increase of occurrence (frequency), size and strength of a number of climate related threats and hazards. Adaptation measures, associated to resilience indicators and linked to the impact of the aforementioned dimensions of climate-change have to be integrated into the EU-CIRCLE solution, currently under development.

As mentioned in D1.4, the proposed methodology can contribute to a diverse number of initiatives related to the Sendai Framework for DRR such as:

- ✓ ***improving risk understanding - hazard characterization***: WP2 is completely devoted to the understanding of how climate parameters and secondary hazards (forest fires, floods, landslides) will change in magnitude and frequency under different future climate scenarios.
- ✓ ***exposure and vulnerability analysis***: The hazard characterization when combined with CI related data (related climate thresholds, building standards such as EUROCODES) could provide as assessment of the CI exposure to multi-hazards and links between vulnerabilities of CI and damages caused by extreme hazards (WP3)
- ✓ ***risk assessment***: The risk will be determined using a multi-hazard approach fully compatible and interoperable to existing frameworks set out in the National Risk Assessment Plans and the Directive 114/2008 on CI protection. Risk estimates will be based not only on direct impacts to the CI but also on the society.(WP3)

- ✓ ***improving institutional capacity on disaster risk reduction:*** the potential use of the EU-CIRCLE by the end-user community will allow to significantly enhance the CI capacity for enhancing CI resilience against multiple hazards, even domino ones
- ✓ ***strengthening Early Warning Systems***: Although not within the scope of the project per se, EU-CIRCLE could be used as an early warning system for early identifying risks to interconnected CI. The substitution of climate data with seasonal prediction models or even operational numerical weather products could provide a unique service for CI operators, as presently such systems are not available.

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11 References

[1] **D 1.4.** EU-CIRCLE Report on detailed methodological framework, Initial version

[2] **DEFRA (2002**): Horizon Scanning & Futures Home. Online in: Internet. URL: http://horizonscanning.defra.gov.uk/. Last visit 15.7.2011.

[3] **Gill Ringland (2006**): Scenario Planning: Managing for the Future. John Wiley and Sons Ltd., West Sussex, England.

[4] **Kees van der Heijden (2005)**: Scenarios:The art of strategic conversation. John Wiley and Sons Ltd., West Sussex, England.

[5] **Tom Ritchey (2013):** General Morphological Analysis: A general method for non **-** quantified modelling. Swedish Morphological Society. Presented at the 16th EURO Conference on Operational Analysis, Brussels, 1998 (revised 2013)

[6] **Poteralska, B. and Sacio-Szymanska, A. (2014)** : Evaluation of Technology Foresight Projects, European Journal of Futures Research 15:26

[7] **D 1.4.** EU-CIRCLE Report on detailed methodological framework_Initial version

[8] Climate consultants include both Climate and Hazard modelers

[9] **Rinaldi, S. M., Peerenboom, J. P., and Kelly, T. K. (2001).** Identifying,understanding and analyzing critical infrastructure interdependencies. IEEE Control Syst. Mag. 21(6), 11–25

[10] **The Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007a** – The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC

(ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7 Paperback)

[11] **The Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007b** – Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. (978 0521 88010-7 Hardback; 978 0521 70597-4 Paperback)

[12] **The Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007c** – Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. (978 0521 88011-4 Hardback; 978 0521 70598-1 Paperback)

[13] **Tebaldi, C., Strauss, B. H., & Zervas, C. E. (2012**). Modelling sea level rise impacts on storm surges along US coasts. Environmental Research Letters, 7(1), 014032.

[14] **Kapakis I (2007)** Forest fires in Greece. Crisis Response J World Wide 4:20–21

[15] ZKI Fire Service (https://www.zki.dlr.de/)

[16] **Mitsakis, E., Stamos, I., Papanikolaou, A. et al. Nat Hazards (2014)** Assessment of extreme weather events on transport networks: case study of the 2007 wildfires in Peloponnesus. 72: 87. doi:10.1007/s11069-013-0896-3

[17] http://www.gscp.gr/ggpp/site/home/independent/ECFF/health_issues.csp

[18] **Davidson C (2007)** Greece prepares to count fire cost. http://news.bbc.co.uk/2/hi/europe/6968799.stm. Accessed 30 Nov 2012

[19] **United States Agency International Development (2007)** Annual report for fiscal year. Office of U.S. Foreign disaster assistance

[20] **B.Wisniewski and T.Wolski (2011)** Physical aspects of extreme storm surges and falls on the Polish

coast. Oceanologia, 53 (1-T1), 2011.pp 373-390

[21] **Irina Stipanovic Oslakovic, Herbert ter Maat, Andreas Hartmann AND Geert Dewulf (2012).** Climate Change and Infrastructure Performance: Should We Worry About? Procedia - Social and Behavioral Sciences, Volume 48, 2012, Pages 1775-1784. Transport Research Arena 2012

[22] **Bosello, F., Nicholls, R., Richards, J., Roson, R., Tol, R.S.J., 2012.** Economic impacts of climate change in Europe: sea-level rise. Climatic Change 112, 63–81, http://dx.doi.org/10.1007/s10584-011-0340-1

[23] **Heberger, M., Cooley, H., Herrera, P., Gleick, P., Moore, E., 2011.** Potential impacts of increased coastal flooding in California due to sea-level rise. Climatic Change 109 (Suppl. 1) S229–S249.

[24] **Van Koningsveld, M., Mulder, J.P.M., Stive, M.J.F., van der Valk, L., van der Weck, A.W., 2008.** Living with sea-level rise and climate change: a case study of the Netherlands. Journal of Coastal Research 24 (2) 367–379.

[25] **Breil, M., Gambarelli, G., Nunes, P., 2005.** Economic valuation of on site material damages of high water on economic activities based in the City of Venice: results from a dose-response-expert-based valuation approach. FEEM Nota di lavoro 53.2005. , http://ssrn.com/abstract=702965

[26] **Smith, J., Lazo, J., 2001.** A summary of climate change impact assessments from the US Country Studies Programme. Climatic Change 50, 1–29

[27], [28] **EEA Report: No 8/2014.** Adaptation of transport to climate change in Europe. Challenges and options across transport modes and stakeholders. ISSN 1977-8449

[29] **FFWC, 2007.** Web-based database, Flood Forecasting and Warning Centre (FFWC),Bangladesh Water, Development Board. URL ⟨http://www.ffwc.org/⟩

[30] **Ahmed, A.U., 2008.** Desakota Phenomenon Observed in Satkhira – Khulna – Jessore – Dhaka Corridor in South Western Bangladesh; Part II F1 Case Study.⟨http://r4d. dfid.gov.uk/PDF/Outputs/EnvRes/Desakota_PartII_F1CaseStudyBangladesh.pdf⟩.

[31] **Ahmed, A.U., Neelormi, S., Adri, N., 2007.** Entrapped in a Water World: Impacts of an Adaptation to Climate Change Induced Water Logging for Women in Bangladesh. Centre for Global Change, Dhaka, p. 8.

[32] **Rahman, M.A., 2010.** Coastal zone management of Bangladesh. Presented at the International Geosphere – Biosphere Programme Synthesis Integration and Exploration: Global Environmental Change and Sustainable Development; Needs of Least Developed Countries (IGBP-LDCs) Synthesis Workshop, Maputo Mozambique September 20–22, 2010.

[33] Miyan, M.A., 2012. Coastal zone management of Bangladesh. Fourth Session of the Joint WMO – IOC Technical Commission for Oceanography and Marine Meteor- ology (JCOMM-4) Yeosu, Republic of Korea, May 23– 29, 2012.

[34] Sarwar, G.M., 2008. Landslide Tragedy of Bangladesh, The First World Landslide Forum, 18– 21 November 2008. United Nations University (UNU), Tokyo, Japan

[35] **Rahman, M.A., 2013.** Natural and traditional defense mechanisms to reduce climate risks in coastal zones of Bangladesh. Climate extremes and challenges to infrastructure development in coastal cities in Bangladesh. Presented at IGBP- APN Write a paper workshop, August 26 – 30, 2013. Windsor Suites Hotel, Bangkok, Thailand.

[36] **Dhaka Tribune, 2013.** Spate of deaths from landslides continues ⟨http://www.dhakatribune.com/bangladesh/2013/jul/29/spate-deaths-landslides-continues⟩

[37] **NCSRD** publication (pending)

[38] **Mitsakis, E., Stamos, I., Papanikolaou, A. et al. Nat Hazards (2014.** Assessment of extreme weather events on transport networks: case study of the 2007 wildfires in Peloponnesus.) 72: 87. doi:10.1007/s11069-013-0896-3

[39] http://www.southernfireexchange.org/SFE_Publications/factsheets/2011-6.pdf

[40] **Rolph, G.D., Draxler, R.R., Stein, A.F., Taylor, A., Ruminski, M.G., Kondragunta, S.,Zeng, J., Huang, H.-C., Manikin, G., McQueen, J.T., 2009**: Description and Verification of the NOAA Smoke Forecasting System: The 2007 Fire Season.In Weather and Forecasting 24(2) · April 2009

[41] https://www.eoas.ubc.ca/courses/atsc507/ADM/hysplit/BAMS-Hysplit%202016.pdf

[42] http://playground.airfire.org/login.php?next=/index.php

[43] **Dasgupta, S., Laplante, B., Murrey, S., Wheeler, D., 2009.** Climate Change and the Future Impacts on Storm-Surge Disaster in Developing countries Center for Global Development. Working Paper 182, September 2009.

[44] **D3.4** A Holistic CI Climate Hazard Risk Assessment Framework (EU-CIRCLE)

[45**] D3.4** A Holistic CI Climate Hazard Risk Assessment Framework (EU-CIRCLE)

[46] **D1.4** Report On Detailed Methodological Framework (EU-CIRCLE)

12 Annex I

Relevant questions concerning the impact of climate stressors and future climate perspective that EU-CIRCLE modeling and DSS tools should address based on projected climate change data:

Stakeholder (s)	CI operators, Authorities and Administration
Question	*For a specific region and for a concrete time period (20-100y)* a. When (month/year) rainfall intensity (amount of rain in a specific catchment/rainfall duration) will exceed a certain threshold? b. When (month/year) snowfall height (i) and intensity (ii) will exceed a specific threshold? c. Assess periods (month/year) when temperature will continuously exceed a specific threshold value for a specific number of days d. Assess periods (month/year) of days without (significant) rain
Hazard	Climate stressors to critical infrastructure
Risk/Impact	Degradation of operational performance Societal disruption due to climate events

Stakeholder (s)	Authorities and Administration
Question	*For a specific region and for a concrete time period (20-100y)* a. What will be the increase of fire frequency in the region? b. What will be the change in fire behavior (due to climate change) in specific areas? c. When (month/year) fire risk indices will be in the higher risk level d. Assess areas of high fire intensity to avoid exposure of infrastructure to risk or consider retrofitting measures
Hazard	Wildfire
Risk/Impact	- Siting of vulnerable infrastructures during planning phase - Retrofitting of existing infrastructures against wildfire risk - Citizen awareness for fire risk

Stakeholder (s)	Transport operators

Question	*For a specific region and for a concrete time period (20-100y)* How many fog events (increase %) are expected/year
Hazard	Fog formation
Risk/Impact	- Reduced visibility in roads - Impact to take-off and landing in airports

Stakeholder (s)	CI operators, Authorities and Administration
Question	*For a specific catchment:* - How the current flood return period thresholds (20,50, 100y) change i.e. a. How the extent of the flood plain will change? and b. how the water height map will be? - How often a particular area will be flooded within a certain period?
Hazard	Flood
Risk/Impact	- Flood of the road transport network - Flooding of basements and buildings - Damages and disruption to communication links, power plants, roads and bridges - Psychosocial effects - Eventual people dislocation and dysfunction of normal life and local economy for a period much beyond the duration of the flooding - Loss of land value and lack of development locally - Spillover effects even in adjacent non-flooded areas

Stakeholder (s)	CI operators
Question	*For a specific infrastructure* How the change of the climate regime (due to climate change) will influence (speed up) the aging (deterioration rate)?
Hazard	Climate stressors to critical infrastructure
Risk/Impact	Increased vulnerability influencing the performance and robustness of the CI (aging often acts together with other factors such as design, maintenance, and operation e.g. the more devastating bridge collapses were not due to age but rather to combinations of design, maintenance, operation, and the environmental stresses...)

Stakeholder (s)	CI operators
Question	*For a specific catchment* How the extent of the flood plain (innundated area) will change within the period (mapping) to consider retrofitting and additional countermeasures
Hazard	Flood
Risk/Impact	- Flooding of CI elements - Problems accessing CI assets

Stakeholder (s)	Energy sector operators
Question	*For a specific critical service* Need to assess the change in (daily) temperature ranges and annual distribution of cooling Degree Days (T>24^{o}C) or heating* Degree Days (T>24^{o}C). In addition, how this change may influence the demand of the service provided (e.g. heating or cooling demand) in order to anticipate the service provision resilience. *Heating degree days are a measure of how much (in degrees), and for how long (in days), the outside air temperature was below a certain level. They are commonly used in calculations relating to the energy consumption required to heat buildings.
Hazard	Climate stressors
Risk/Impact	- Overloading of the power grid - Failure to fill customers SLAs - Reputation issues

Stakeholder (s)	Transport operators
Question	How the river flow will change due to climate change? What will be the peak river flow rate for the 100y return period and 24h storm events?
Hazard	Rainfall, Flood
Risk/Impact	This may influence bridge construction scour and erosion.

Stakeholder (s)	Transport operators
Question	*For a specific road axis and for a specific time period (10-20y)* - What will be the change of the freeze-thaw cycle due to climate change? - What is the impact of climate change to rainfall erosivity patterns? - Assess high temperature and increased solar radiation patterns. *For each of the above cases, stressor response functions can be determined.*
Hazard	Temperature, Solar radiation
Risk/Impact	- Freeze-thaw cycle will influence rutting of paved roads (maintenance costs) - Rainfall erosivity shall increase erosion of unpaved roads - High temperatures and intense solar radiation are responsible for cracking paved roads and reduction of the life-cycle of asphalt roads.

Stakeholder (s)	Water management operators
Question	*For a specific urban area and a concrete time period (20,50, 100y)* What will be the change of storm intensity due to CC (within a 24h period and with resolution of 3h)?
Hazard	Storm
Risk/Impact	Salt water intrusion in ground water aquifers

Stakeholder (s)	Fire management authorities
Question	*For a specific region and time period (20,50,100y)* - What will be the change in the fire occurrence? Reconsider the structural fire risk zoning (mapping) based on climate change data assessment. Compare actual vs anticipated fire risk distribution. - What will be the change in fire frequency? Revise the fire return interval, based on climate change data assessment. Compare actual vs anticipated fire risk distribution. - What will be the change to the extent of the dry period? Elaborate ombrothermic diagrams for a region using assessed (climate change) data. This may redefine the fire season and/or the extent of the dry period.
Hazard	Forest fire, Temperature, Rainfall
Risk/Impact	- More frequent wildfires - Spatial extent of potential fire occurrence - Extent of the dry period

Stakeholder (s)	Water management operators
Question	*For a specific region and time period (20,50,100y)* What will be the projected annual distribution of rainfall within the envisaged period? Reconsider dikes efficiency and performance based on assessed climate change precipitation data.
Hazard	Rainfall anomalies
Risk/Impact	- Dikes efficiency - Water supply efficiency

Stakeholder (s)	Transport operators
Question	*For a specific region and time period (20,50, 100y)* What will be the number of days with Tmax (heat stress) above certain value (e.g. 32^{o}C)?
Hazard	High temperature
Risk/Impact	Persisting high temperatures can be linked with: a. Problems in steel bridges b. railroad track deformities and shortened life expectancy of rail and c. change in required airport runway length and decreased airport lift disturbance to transport infrastructure electronics

Stakeholder (s)	Transport operators
Question	*For a specific region and time period (20,50, 100y)* What will be the number of days with Tmean below 0 ^{o}C and -7 ^{o}C (cold waves)?
Hazard	Low temperature
Risk/Impact	Very low temperatures and cold waves is linked with: a. problems in cable bridges b. damages to roadway integrity c. fatigue of railway infrastructure material d. freezing sea and structures in port and marine operations

Stakeholder (s)	Transport, Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* - What will be the number of (and which are the) days with extreme rainfall? Depending on the catchment extent define values e.g. a.>30-50mm/day and b. >100mm/day (if possible downscale from 24h to 3h period). - Annual rainfall pattern based on daily precipitation values and comparison with actual available patterns
Hazard	Rainfall
Risk/Impact	- Flooded roads or rail stations - Reduced visibility, - Electricity breakdown

	- Destabilization of embankments, - Reduced safety for transport network users.

Stakeholder (s)	Transport operators
Question	*For a specific region and time period (20,50, 100y)* How many and which will be the days with extreme rainfall value i.e. R>150-200mm total amount in a single day? Data to be combined with geological information and along transport network axes.
Hazard	Extreme rainfall, sliding
Risk/Impact	- Risk of landslides, - Soil instability - Reduced transport safety - Lush flow avalanches that may impact transport safety

Stakeholder (s)	Transport operators
Question	*For a specific region and time period (20,50, 100y)* Assess the number (and time period) of days with significant snow fall (Rs 1-10cm/d, Rs>10cm/d).
Hazard	Snowfall
Risk/Impact	- Snow accumulation and relative transport problems (road blockages, traffic jams, reduce speed etc.) - Combined with below zero temperatures and high wind speeds (or gusts) above 17m/s it can be linked with • Reduced visibility and transport safety • Interruption of infrastructure operations • Ice on roads • Icing of exposed infrastructure elements - Delays and cancellations of flights in airports

Stakeholder (s)	Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* What is the annual distribution of the amount and distribution of solar radiation combined with cloud cover?
Hazard	Solar radiation, Cloud cover
Risk/Impact	- Impact the performance and availability of renewable energy sources - Revision of the siting and management of the renewable sources installations
Stakeholder (s)	Transport operators
Question	*For a specific region and time period (20,50, 100y)* What is the number of days with extreme winds and wind gusts (indicative thresholds above 17m/s and 25m/s)? Compare with actual figures.
Hazard	High winds

Risk/Impact	Impact can be associated with: - Delays to berthing and cargo handling operations in ports - Problems on ship navigation - Reduced travel speed and delays due to road accidents and incidents - Reduced transport safety - Disturbance to traffic infrastructure electronics

Stakeholder (s)	Port and transport operators
Question	*For a specific region and time period (20,50, 100y)* What will be the sea rise level, which may be associated with permanent or temporarily inundation of infrastructure assets?
Hazard	Sea level rise
Risk/Impact	- Sea port infrastructures can be made unavailable progressively and retrofitting measures might be required - Erosion of coastal infrastructures are expected

Stakeholder (s)	Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* What will be the number of days with Tmax (heat stress) above certain value (e.g. 32^{o}C)?
Hazard	High temperature
Risk/Impact	This can be linked with: - Affection in power generation, transmission and transformer substations - Increased resistance of overhead lines - Needs of cooling water for thermal power plants - Availability of hydropower supply

Stakeholder (s)	Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* Identify patterns of heavy or extreme rainfall (and relative intensity) i.e. amount of 30-50mm/day or 100mm/day
Hazard	Rainfall
Risk/Impact	- Inundation of energy infrastructure components - Power failure and breakdown of network

Stakeholder (s)	Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* Identify periods with extreme snowfall (accumulation), blizzard (combined with strong winds) and icing (temperatures below 0)
Hazard	Snowfall, Blizzard
Risk/Impact	- Reduced performance due to ice accretion on overhead lines and - Disruption caused by icing of energy infrastructure elements

Stakeholder (s)	Energy sector operators
Question	*For a specific region and time period (20,50, 100y)* Identify extreme wind values (gusts of 6h) and time periods of occurrence.
Hazard	Extreme winds
Risk/Impact	This may lead to toppled pylons, downed overhead lines and forced wind turbine shut down

Stakeholder (s)	Energy operators
Question	- What will be the sea rise level within a specific period in a specific region? - When the sea level will rise a specific height above current level? - Compare the time to reach the threshold with the time required to retrofit or relocation.
Hazard	Sea level rise
Risk/Impact	This may lead to erosion of coastal structures

Stakeholder (s)	Water operators
Question	*For a specific region and within a certain time period:* Which are the periods with short-term (3<t<6 months with no significant rain) or long-term (>6 months) drought?
Hazard	Drought
Risk/Impact	Long-term droughts lead to - increased water demand and pressure on infrastructure, - loss of potable water/lowered water table, - dam failure, - food shortages, - risk for conflagrations and mega-fires Short-term droughts lead to - increased water demand and - high risk of wildfires

Stakeholder (s)	Water operators
Question	*For a specific region and within a certain time period (20,50, 100y):* What will be the number of days with Tmean below 0 ^{o}C and -7 ^{o}C (cold waves)?
Hazard	Low temperature
Risk/Impact	Very low temperature may be linked with: - Rupture of drinking lines and - Rupture of water storage tanks

Stakeholder (s)	Water operators
Question	Identify patterns of continuous days with snow cover above a specific threshold, combined with temperatures below 0^{o}C.
Hazard	Snow cover, Low temperature
Risk/Impact	Duration and extent of snow cover may reduce water storage capacity

Stakeholder (s)	Water operators
Question	*For a specific region and within a certain time period (20,50, 100y):* What (where) is the expected sea level rise (above a certain threshold)? What is the assessed intensity of sea storm and storm surges?
Hazard	Sea level rise, Storm and storm surge
Risk/Impact	Saltwater intrusion in groundwater aquifers

Stakeholder (s)	Wastewater operators
Question	*For a specific region and time period (20,50, 100y)* What will be the number of days with Tmax (heat stress) above certain value (e.g. 32^{o}C)? What is the number and extent of Short-Term and Long-Term droughts?
Hazard	High/extreme temperatures, drought
Risk/Impact	This can be linked with increased demand for water delivery and collection systems

Stakeholder (s)	Wastewater operators
Question	*For a specific region and within a certain time period (20,50, 100y):* What will be the number of days with Tmean below $0\,^{o}$C and $-7\,^{o}$C (cold waves)?
Hazard	Very low temperatures
Risk/Impact	- Potential rupture of sewage lines - Potential rupture of sewage storage tanks - Failure of frozen-core dams on tailing ponds due to thawing

Stakeholder (s)	Wastewater operators
Question	*For a specific region and within a certain time period (20,50, 100y):* Which will be the extent, water depth and flow hydraulics of expected floods based on climate change projected data?
Hazard	Flood
Risk/Impact	- Urban drainage system failure - Failure of wastewater treatment facilities (retrofitting needed) - Pipeline ruptures - Flooded waste-water management assets