EU-CIRCLE

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

D1.3 EU-CIRCLE strategic context

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Statement
This report determines the strategic concept of EU-CIRCLE, a high level description of the scope, objectives and pathway for assessing resilience of interconnected and interdependent critical infrastructures to climate change. It is also linked to the necessity for alignment of the methodological framework with the CIRP modelling framework.

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Preparation Slip			
	Name	Partner	Date
From	Athanasios Sfetsos	NCSRD	10/02/2016
Reviewer	Clemente Fuggini	DAPP	28/02/2016
Reviewer			
For delivery	Athanasios Sfetsos	NCSRD	01/04/2016

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Executive Summary

The scope of D1.3 is to define the strategic context of the EU-CIRCLE project, establishing the specific elements that constitute the project and its interconnections and dependencies. D1.3 is a multi-faceted document, a roadmap for project activities elaborating elements from:

- Reports by the International Panel on Climate Change (IPCC);
- EU and national policies related to the scope of EU-CIRCLE: critical infrastructure protection, climate adaptation, risk assessment of natural hazards;
- Best practices and perceptions in the critical infrastructure community (owners, operators, national authorities);
- Results of previous EU and nationally funded projects.

The strategic framework of EU-CIRCLE is the result of a lengthy discussion, data collection and data assessment process conducted by the project partners, the members of the project's International Advisory Board (D9.3), and external experts in kick-off meeting (Athens Greece, 9 & 10 June2015), in the 2nd project meeting (Nicosia Cyprus, 26 & 27 November 2015), in the joint EU-CIRCLE NIST-CORE workshop (Athens Greece, 5-7 October 2015), in bilateral discussions of EU-CIRCLE partners which are National Contact Points (NCP) in accordance to the Directive 114/2008 and other EU counterparts, in the meeting of FP7 and Horizon 2020 projects for discussing possible contributions to the forthcoming Special Report on 1.5°C foreseen by the UNFCCC Decision at COP21 on the Paris Agreement, (Brussels February 1, 2016), in unstructured interviews and discussions between EU-CIRCLE partners and subject matter experts on numerous occasions and in regular skype and phone calls between WP participants discussing specific elements of this Deliverable.

As a result of the above consultations and discussions, EU-CIRCLE aspires to present a holistic methodological framework, as shown schematically and analytically in Figure 1. It is focused on the characterization of the CI and their properties in accordance with their critical threshold and how they interconnect. The result is a set of combined direct and indirect impacts that can help to assess the risk involved due to climate hazards and proceed with an estimation of the CI resilience. In order to account quantification estimation of the interconnected CI, EU-CIRCLE has proposed the development of resilience indicators which will be based on the following:

- Climate hazards and its likelihood metric (e.g. return period) in relation to CI thresholds
- CI performance under normal operation and climate change impacts,
- Impact related metrics
- Uncertainty of the derived results
- Resilience constituents estimates and collective resilience indices
- Multiple Metrics combining any of the above

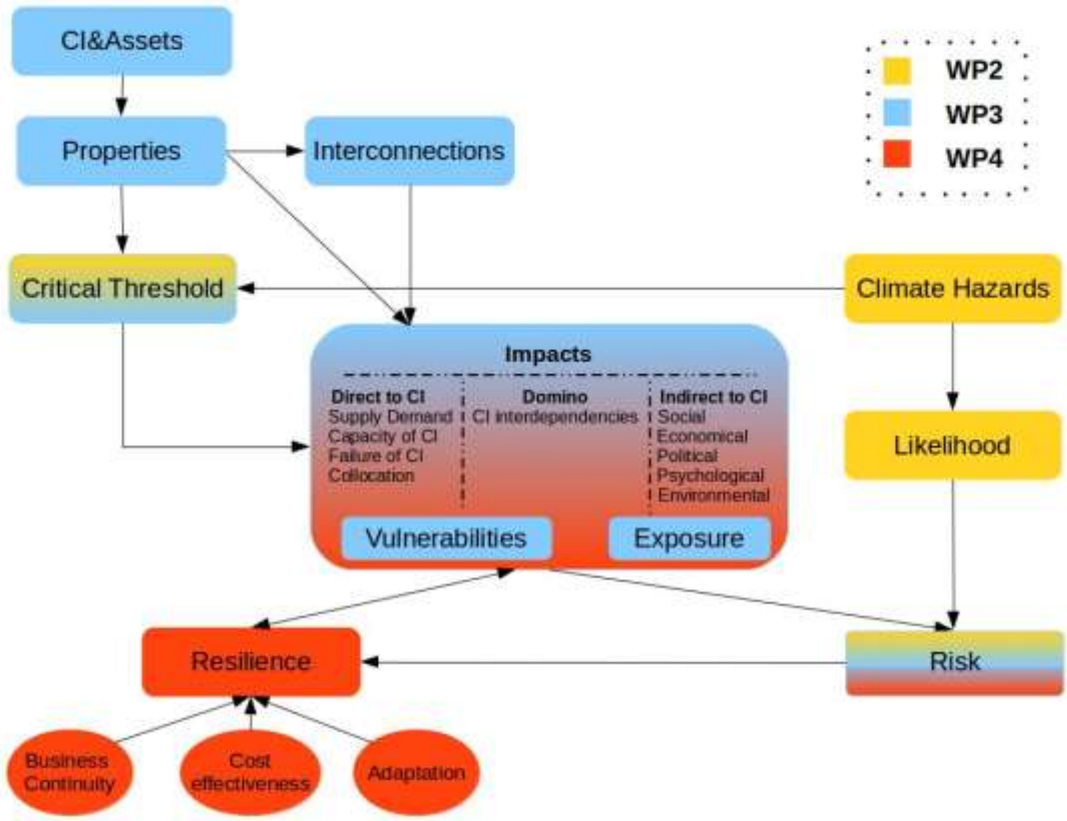

Figure 1 - EU-CIRCLE framework high level description

The infrastructure sectors that are pertinent to EU-CIRCLE analysis were identified according to Directive 114/2008, SWD (2013) 13, SWD (2014) 134, SWD (2013) 318, IPCC AR5 report and are listed below:

- Energy Sector
- Transportation
- Water – Sewage
- ICT – Information & Communication
- Chemical Industry
- Health Sector
- Government Services

Within EU-CIRCLE, climate parameters are the driving force behind the conducted analysis. They provide an estimation of the likelihood of the climate induced risks to infrastructures and will contribute to the identification of the climate critical infrastructure thresholds. As such, the climate change related effects have been divided into two different categories, as reported in Table 1 below:

- Climate drivers, which are the direct output of simulation models (GCM/RCM, seasonal forecasting models) and observation data
- Climate hazards, which are direct consequence of climate drivers, are modelled using post-processing algorithms of the climate drivers and new simulation models from climate simulation models.

Table 1. EU-CIRCLE climate parameters and their interconnection

Climate drivers	Climate hazards
Temperature	Heat waves, cold snaps
Precipitation (rain / snowfall) - humidity	Floods
Winds	Forest Fires
Cloud / fog	Droughts
Solar radiation	Earth movement caused by climate drivers such as rain (landslide, erosion, avalanches)
Sea level rise	
Ice , frost	
Strom surges, waves	

Moreover, according to EU documents the impacts of climate change could be multi-dimensional and lead to cascade and domino effects. Within EU-CIRCLE the impacts of climate hazards to interconnected infrastructures are associated with two discrete types of impacts:

- Direct impacts to the operation of the infrastructure
    - Changes in the provision of CI "services and products" to the society
    - Partial or total failure of the infrastructure
    - Domino effect
- Indirect impacts, related to the externalities of the CI operation, also including the societal costs

The focal point of the EU-CIRCLE project is resilience, which according to several documents in EU-CIRCLE D1.1 "EU-CIRCLE Taxonomy" and section 4.6 in this document, encompasses the ability/capacity of any CI (or their network) to prevent, protect and prepare for impacts of climate change. A critical objective of the project is to define the constituent components of resilience that fit its scope provisionally accounting for elements such as prevention, reducing potential impacts, optimization of resources, adapting to climate risks and accounting of CI dependencies.

All the above will be incorporated and utilised in the Climate Infrastructure Resilience Platform (CIRP). CIPRP main objective is to become a web-based resilience management software, based on climate risk dynamic approach to critical infrastructure using the Consequence-based Management (CBM) methodology. The proposed CIRP will be implemented through graphical user interface [GUI], with a straightforward installation, and amble capacity for users to introduce customized information and data. The generated scientific knowledge that will be introduced within CIRP will be progressively tested in order to ensure a) the highest possible scientific standards including the introduction of the uncertainties within this process and b) the generated results are meaningful and clearly interpretable for the EU-CIRCLE stakeholder community. CIRP will provide a web-based modelling environment where multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner. For assessing the resilience of infrastructures to climate pressures, EU-CIRCLE will create a reference virtual environment termed as SimICI. It shall serve as a testbed for all developments, integrations, and evaluations performed, whereas after the project's completion SimICI shall be a legacy providing a further exploitation mechanism.

Finally the EU-CIRCLE methodology will be validated across five case studies, namely: .

- ✓ Case Study 1: Extreme Drought and forest fire impact on electricity and transport networks, concerning a cross border event between France and Italy,
- ✓ Case Study 2: Storm and Sea Surge at a Baltic Sea Port , Gdynia Poland
- ✓ Case Study 3: Coastal Flooding (surface water, highway, sewer and watercourse flooding) across Torbay, UK
- ✓ Case Study 4: International Event, concerning disasters impact to local community and test findings of research in Disaster Resilience to Climate Change in Bangladesh
- ✓ Case Study 5: Rapid Winter Flooding (melting ice, narrow mountain streams, flooding) around Dresden, Germany

In addition to this and to complete the picture, the project website (http://www.eu-circle.eu/wp/), social media presence, bi-annual newsletters and scientific (open access) papers and conference proceedings will increase awareness of EU-CIRCLE through the user's community. In line with this, the common goal of the project's partners is the developed framework, standards and methodologies to be accessible to the stakeholders who have a confirmed interest in creating customised and innovative solutions.

Contents

Table of abbreviations	
Abbreviations	Meaning
ACORD	Association for Cooperative Operations Research and Development
API	Application Programming Interface
CAPEX	Capital Expenses
CEN	Commission for European Normalization
CF	Climate Forecast
CI	Critical Infrastructure
CIM	Common Information Model
CIRP	Climate Infrastructure Resilience Platform
COM	Commission
COP21	Conference Of the Parties
CORDEX	Coordinated Regional Climate Downscaling Experiment
DoA	Description of the Action
EC	European Commission
EEA	European Environmental Agency
EPCIP	European Programme for Critical Infrastructure Protection
EU	European Union
FP7	Seventh Framework Programme
CHARMe	Characterization of metadata to enable high-quality climate applications and services
GCM	Global Climate Model
GHG	Greenhouse Gases
GUI	Graphical User Interface
IPCC	International Panel on Climate Change
JRC	Joint Research Center
KPI	Key Performance Indicators
NCP	National Contact Point
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
OPEX	Operational Expenses
PIEVC	Public Infrastructure Engineering Vulnerability Committee
QA/QC	Quality Assurance / Quality Control
RCM	Regional Climate Model
RCP	Representative Concentrations Pathways
SimICI	Simulated Interconnected Critical Infrastructure
SSP	shared socioeconomic pathway
SWD	Staff Working Document
UFNCCC	United Nation Framework Convention on Climate Change
UNISDR	United Nation International Strategy For Disaster Reduction
WGII	Working Group II
WMO	World Meteorological Organisation

1 Introduction

The scope of D1.3 is to define the strategic context of the EU-CIRCLE project, defining the specific elements that constitute the project and its interconnections and dependencies. The main scope of EU-CIRCLE is to generate a scientifically verified framework to estimate the resiliency of critical infrastructures to climatic hazards. The proposed framework should build upon a comprehensive assessment of multiple climate risks and related natural hazards, including those that are directly attributed to climate parameters, such as floods, forest fires, droughts, etc. The resilience of the infrastructures, in the EU-CIRCLE perspective, encompasses the operational components of the infrastructures in a holistic manner, and not only its structural integrity and its capacity to maximize business output under future climate conditions.

Critical infrastructures are commonly designed, built and maintained according to rigorous standards[1][2] [1]–[3] in order to withstand the climate and weather-related pressures of the location they have been built in, but shifts in climate characteristics due to climate change increase the range and type of potential risks, or expose specific CI to new risks not previously considered. Most infrastructures being built today are expected to last for several decades, although it should be noted that some infrastructures are built without a specific time frame in mind. A main EU-CIRCLE objective [4] is to provide scientific evidence in better understanding how future climate regimes might affect the interconnected CI during their lifespan, assess and propose the most cost-effective adaptation measures to manage these changes. This requires a comprehensive identification and assessment of risks and uncertainties associated with climate change and an understanding at the strategic/policy level that promoting adaptation of current infrastructures may be a more advantageous policy than relying on rebuilding or redesigning infrastructure after a disaster has occurred.

The increasingly dependent, interdependent and interconnected nature of European critical infrastructures exposes previously unseen risks, new vulnerabilities and opportunities for disruption across the CI networks. Current analysis of historical incidents indicates that CI vulnerability tend to be focused on extreme weather events that can disrupt the normal operation of infrastructures, often impacts cascading across infrastructures because of extensive interdependencies between them [5]. Acknowledging that infrastructure's vulnerabilities and impacts go far beyond physical damages [6],[7], EU-CIRLCE will be concerned with an assessment of the impacts to the services provided by CI, addressing impacts associated with the repair, and/or replacement of services but also including the externalities of the infrastructures operation, societal costs, environmental effects, and economic costs due to suspended activities.

Critical infrastructure resiliency [8] encompasses a much wider set of activities than that of conventional practices in the protection of critical infrastructures against multiple threats, and includes activities for prevention, protection and preparedness against natural hazards. Resiliency against climate change hazards includes multiple of activities, ranging from emergency response plans and capabilities, recovery plans, long term investment plans and changing technological elements of the infrastructures during its lengthy lifespan. Also, as European CI are large scale projects often with a cross-border dimension, EU-CIRCLE will illustrate how incidents affecting infrastructure in one country have the potential to affect operations in infrastructure in other countries. This introduces a key scope of EU-CIRCLE which is the development of harmonised approaches which can be understood and accepted by a diverse set of EU-CIRCLE users (section 2) provided that the responses of the EU-CIRCLE questionnaire (WP1) are translated into their requirements and working language.

The main objective of the adaptation element as introduced within EU-CIRCLE will be, based on the identification and quantification of risks from climate related hazards, to develop a range of options that will allow a CI operator to avoid, transfer, accept, reduce or share those risks. Options could vary from the provision of physical protection through the relocation of assets, or the provision of alternative supplies, or improved arrangements for emergency response. Furthermore, in modern and increasingly networked

[1] http://eurocodes.jrc.ec.europa.eu/
[2] http://standards.cen.eu/

European societies, the EU-CIRCLE approach also places at centre stage the dependencies, interdependencies and interconnections within and between sectors.

The purpose of this Document is to define and explain in details the strategic objectives of the project and reflecting the decisions taken by the consortium on its initial stages shaping its implementation. As such, within this document

1. Section 3, defines how EU-CIRCLE is positioned in the intersection of European and national policies for combating climate change (e.g. National Risk Assessment strategies) and activities for critical infrastructure protection,
2. Section 3.1, describes the policy questions (e.g. How exposed is the an infrastructure of a certain region to a specific climate hazard) related to the resiliency of EU critical infrastructures against climate hazards that EU-CIRCLE should address in a scientifically validated way.
3. Section 4, introduces the guiding principles for delivering a consistent, scientifically valid and verified framework for estimating the resiliency of critical infrastructures to climatic change related hazards,
4. Section 2, defines the potential audience/stakeholders of the project, and the optimal way by which they can interact with the project's objectives and on-going work. (e.g. National, Regional, Local authorities, CI owners & operators, climatologists, …)
5. Section 8, identifies the project's communication, dissemination and exploitation characteristics of the project's elements, and maximise the visibility of the proposed activities.

1.1 Methodological approach

The Strategic Framework of EU-CIRCLE is a comprehensive picture of the project's strategy in order to reach its goals and objectives as described in the DoA. It clarifies in a concise and explanatory detail the specific elements of the project's individual components that need to be put in place. It includes meaningful targets and measures and a sequence of activities that will help the project's partners focus on the key efforts required within each WP they have been allocated to. D1.3 is a multi-purpose document trying to establish the strategic decisions by the consortium on the project execution based on

- Reports by the IPCC (http://www.ipcc.ch/report/ar5/);
- EU and national policies within the scope of EU-CIRCLE: critical infrastructure protection, climate adaptation, risk assessment of natural hazards (section 4);
- Best practices and perceptions in the critical infrastructure community (owners, operators, national authorities) as identified in related literature review and bilateral interviews;
- Results of previous EU and nationally funded projects.

The strategic framework of EU-CIRCLE is the result of a lengthy discussion, data collection and data assessment process conducted by the project partners, the members of the project's International Advisory Board (D9.3), and external experts in:

- The project's kick-off meeting held at National Center For Scientific Research - Demokritos (NCSRD) premises, Athens Greece, 9 & 10 June2015;
- the 2nd project meeting held at the European University Cyprus (EUC) premises, Nicosia Cyprus, 26 & 27 November 2015;

- the joint EU-CIRCLE NIST-CORE workshop held in NCSRD premises, Athens Greece, 5-7 October 2015;
- bilateral discussions of EU-CIRCLE partners which are National Contact Points (CNP) in accordance to the Directive 114/2008 and other EU counterparts;
- Meeting of FP7 and Horizon 2020 projects for discussing possible contributions to the forthcoming Special Report on 1.5°C foreseen by the UNFCCC Decision at COP21 on the Paris Agreement, held in Brussels February 1, 2016.
- unstructured interviews and discussions between EU-CIRCLE partners and subject matter experts on numerous occasions;
- regular skype and phone calls between WP participants discussing specific elements of this Deliverable.

The specific elements analysed in this document, will be reviewed and re-assessed during the development of the following Deliverables:

- ✓ D1.4 Report on Detailed Methodological Framework _ initial version
- ✓ D2.1 Report On Typology Of Climate Related Hazards
- ✓ D3.4 Holistic CI Climate Hazard Risk Assessment Framework V1.0
- ✓ D4.1 EU-Circle CI Resilience Framework To Climate Hazards_ first version
- ✓ D5.1 CIRP Detail Design Document
- ✓ D8.1, D8.2, D8.3 Annual Dissemination And Exploitation Plan
- ✓ D9.5 QA/QC Protocol

In addition, the Consolidation Workshop, Task 1.5 - scheduled for M12 of the project, will bring the target stakeholders and user community of EU-CIRCLE together to discuss the initial work undertaken in the project's first months and provide them with an opportunity to provide additional feed-back. The attendees of the workshop will be invited to review this document to ensure that the strategic context described in this Document is complete and that it does not contain any important omissions and to provide suggestions, where appropriate, for further improvements.

2 Target users of EU-CIRCLE

Table 2. Target Users of EU-CIRCLE
Primary relevance to WP: WP1 & WP8

EU-CIRCLE has an ambitious aspiration of engaging multiple types of potential users for transmitting its foreseen delivered scientific data and reports, use of the Climate Infrastructure Resilience Platform – CIRP open modelling environment, publication to scientific journals and conferences, dissemination and communication material. These have been identified in D8.1 as

- CI community. These include all types of CI owners and operators identified in the EU Directive 114/2008: energy and transport, in the ongoing discussions for its revision (SWD(2013) 318 final) and national policies.
- National Critical Infrastructures Authorities, as identified in the EU Directive 114/2008 and national Laws.
- Civil protection authorities at regional, national and EU level, also closely linked to emergency and first responders.

The main delivery of EU-CIRCLE generated output to this type of community will include customised risk assessment for climate hazards and, the CIRP end-to-end modelling environment that will be able to support customised analysis workflows for regions of interest (accounting for interconnected CI) to single infrastructure, and manage existing "big data"-sets and generated data. EU-CIRCLE shall generate a single integrated risk & resiliency assessment for a region of interest with interdependent CI, overcoming barriers of different risk analysis and metrics, interpretation of results, and ultimately suggesting the cost-effective adaptation options. Additionally, EU-CIRCLE elements could support regional emergency response planning actions optimising the capacity of a region to withstand and bounce back from future catastrophic events.

- Members of the Climatology-Meteorology scientific community and those working in the domain of critical infrastructure protection.

Develop, test and integrate interdependency and consequence modeling in the CIRP environment, and simulations to support decisions to predict and prevent cascading failures. Thus research community will be provided with a state of the science, fully customizable modeling platform to build individual and community scale models that can be used to analyze the effects of infrastructure failure in the wake of future climate patterns.

- Financial Sector & insurance companies

EU-CIRCLE shall allow users of this community to analyze present and future climate scenarios would affect infrastructure, and how the disruption of those essential services would affect other vital sectors of the economy and society. The generated knowledge and the CIRP tool could be utilized for planning, coordination, and science backed decision on investments.

2.1 Key policy frameworks and objectives

Table 3. Relevance European Policies to EU-CIRCLE
Primary relevance to WP: WP1 & WP8

EU-CIRCLE is a research project that aspires to shape a collaborative environment nurturing scientific and operational collaboration, for providing validated scientific support for national and European policies related to its diverse field of applications.

- EU Internal Security Strategy, COM(2010) 673 - The EU Internal Security Strategy in Action, and in particular Objective 5: Increase Europe's resilience to crises and disasters - Action 2: developing an all-hazards approach to threat and risk assessment: guidelines for disaster management will be drawn up, national approaches will be developed, cross-sectoral overviews of possible risks will be established together with overviews of current threats, an initiative on health security will be developed, and a risk management policy will be established;
- The EU Strategy on Climate adaptation, as identified in COM (2013) 216 - An EU Strategy on adaptation to climate change, and detailed in
  - SWD (2013) 137 - Adapting infrastructure to climate change
  - EU Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient
- National Risk Assessment Plans as identified
  - COMMISSION STAFF WORKING PAPER on Risk Assessment and Mapping Guidelines for Disaster Management, SEC(2010) 1626, Brussels, 21.12.2010.
  - COMMISSION STAFF WORKING DOCUMENT, Overview of natural and man-made disaster risks in the EU, SWD(2014) 134, Brussels, 8.4.2014
- European Programme for Critical Infrastructure Protection. In the 5th European Union - United States - Canada Experts Meeting on Critical Infrastructure Protection (Athens, May 2014), climate change was re-affirmed as an emerging issue that requires urgent attention and prompt consideration. All participants identified similar issues and priorities, leading to common agreement that solid and consistent scientific evidence is needed in order to enhance resilience of infrastructures. Related douments:
  - DIRECTIVE 2008/114/EC, on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection, 8.12.2008
  - COMMISSION STAFF WORKING DOCUMENT, on the review of the European Programme for Critical Infrastructure Protection (EPCIP), SWD(2012) 190, Brussels, 22.6.2012
  - COMMISSION STAFF WORKING DOCUMENT on a new approach to the European Programme for Critical Infrastructure Protection Making European Critical Infrastructures more secure, SWD(2013) 318, Brussels, 28.8.2013
- Development of the external dimension of EPCIP. A major objective, that has a clear EU added value deriving from the EU-CIRCLE project, 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.

- 2011 'Council Conclusions on the development of the external dimension of the European Programme for Critical Infrastructure Protection', 3096th Justice and Home Affairs Council meeting, Luxembourg, 9 and 10 June 2011

- Solvency II Directive, Directive 2009/138/EC on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II). Under the requirements of this Directive, Reinsurance Organizations need to maintain sufficient capital in future to cover catastrophe risks appear all the more reasonable.

3 EU-CIRCLE context

Table 4. EU-CIRCLE high level objectives
Primary relevance to WP: horizontally for all project

This document identifies a set of objectives that will enhance the resilience of European Critical Infrastructure to effectively respond to emerging challenges that emerge due to climate change. The main characteristics of European Critical Infrastructures are introduced in the following lines.

- Share a common understanding of terms and concepts on CI. Due to the diverge nature of potential users initially EU-CIRCLE introduced Deliverable 1.1, which produced the EU-CIRCLE glossary and taxonomy.
- They are large scale and extremely costly projects. Therefore EU-CIRCLE performed analyses should take into account the entire life-cycle of the CI: design, building, operation, maintenance, refurbishment, retrofitting, adaptation measures, clean-up and disposal.
- Each infrastructure has unique characteristics, and should be treated as such, although common sector properties / best practices could be considered. These are evident from the design and structural phase of the CI and include its operation phases as well as the economic, societal and cultural environment.
- Their performance characteristics (structural, operational, functional etc.) are susceptible to ageing and degradation.
- Their assets must be constructed and operated to withstand diverse disasters in nature (explosions, fires, floods, heat waves, etc.) and adverse threat ranging from natural hazards (e.g. climate pressures, extreme weather and geo-hazards) to technological accidents, intentional man made actions and cyber-attacks,
- They are inherently and highly interconnected systems at various degrees of complexity and their dependencies and interdependencies could vary considerably.
- Originally designed infrastructures thresholds for climate events, could be modified for different reasons, including natural ones such as ageing, procedural / operational, and due to infrastructure's requirements to adaptation – mitigation

According to the initial discussions made with the different competent communities and in several different events (defined in Section 1.1), the following objectives will be of core interest to the project during its life-time:

1. Shifting from traditional critical infrastructure prevention / protection concepts to resilience, which introduces the element of holistic security framework for multiple time horizons. The objective is to provide a suitable environment for science informed decision where optimal investment decisions are able to cope with present day extreme events and disruption to normality to future anticipated climatic risks.
2. Push for a common understanding between the critical infrastructure and natural hazards communities, as a first step towards the "all hazards approach" identified in EPCIP Directive 114/2008.

3. Introduce the ***element of "resiliency – by – design"*** when assessing the potential impacts of newly planned infrastructures to climate pressures and future time horizons
4. Introduce a complete modelling framework of interdependent and interconnected infrastructures, taking into account CI changes due to climate parameters to the supply/demand of the CI, the capability of the infrastructures, reduced / complete inoperability due to extreme events

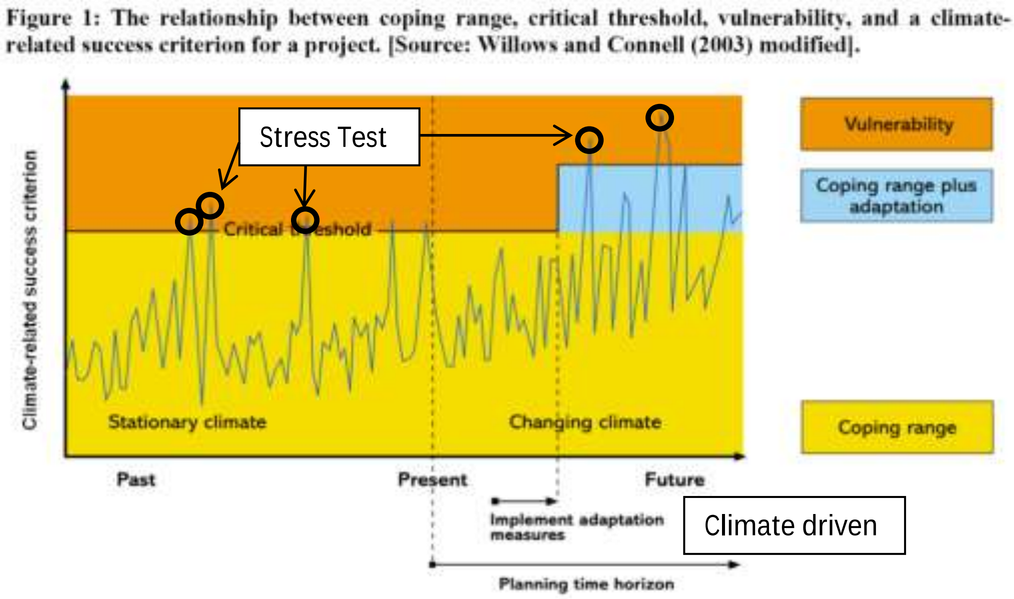

Figure 2- Generic critical infrastructure performance to climate pressures[3]

Taking into account the above properties and identified objectives, EU-CIRCLE aims to improve infrastructure resilience through the development of an integrated approach which takes into account disaster and climate resilience, and cost-benefit analyses for mitigation and adaptation measures. This approach is based on ***the concept of "acceptable risk"***, which is determined by CI owners-operators and national authorities. The "acceptable level of risk" for each infrastructure is inherently linked to a climate critical threshold, which is in turn linked to multiple factors including its structural design, operational and functional elements, location of assets, and overlaying climatic parameters.

Furthermore, CI dependencies, interdependencies will be introduced in the performed analysis, risk assessment and resiliency estimation. The resilience framework that will be established in EU-CIRCLE (section 4.6) shall provide coherent guidance for moving from sector-based climate resilience infrastructure frameworks, into holistic climate resilience plans for entire regions, introducing the interdependencies of heterogeneous infrastructures. This will be based upon the holistic resilience framework (introduced in Task 4.1) and technically supported by CIRP.

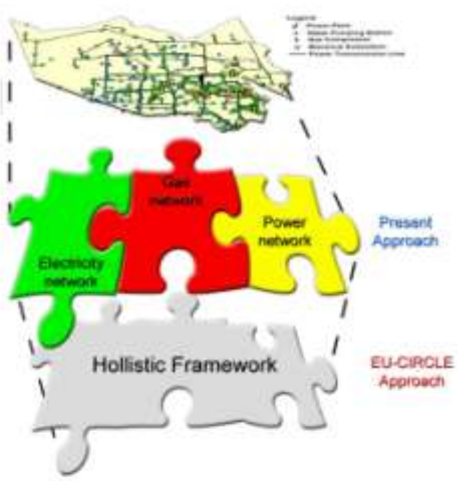

Figure 3- EU-CIRCLE holistic resilience framework

Following the conceptual Fig.1, climate thresholds of each infrastructure project may be breached more frequently and/or in

[3] P.15, COMMISSION STAFF WORKING DOCUMENT, Adapting infrastructure to climate change, SWD(2013) 137,

greater magnitude in a future changing climate. Thus, infrastructures operating within a changing climate regime may be exposed to threshold exceedances, that were once considered acceptable, too costly and disastrous and therefore "unacceptable". Infrastructures therefore, must adapt in order to function within tighter margins between "normal" operation and critical thresholds.

A main scope of EU-CIRCLE is to provide a suitable theoretical framework introduced in the CIRP for allowing potential users to select improvements to achieve an "acceptable level of risk" at an acceptable cost. In that perspective and using the provided EU-CIRCLE methodological approach, users of CIRP can conduct assessments to determine the risk(s) that interconnected infrastructures are exposed to and take steps to improve resilience to climate change impacts. The CIRP tool with thus directly support the EU policy areas [9], where climate resilience has already been introduced in obligatory cost-benefit analyses during the project development phase.

Figure 1, also provides the driving force of different analyses targeted by the EU-CIRCLE and introduced within CIRP. Two different alternatives exist, which will be implemented within EU-CIRCLE:

- "Stress – test" approach where the "climate threshold" is the driver of the analysis. Stress tests usually associate the severity of a hazard or a disruptive event with the potential impact on a system or on the society as a whole, assuming full exploitation of the vulnerabilities of CI including breaching all defense systems [10]. Once CI related critical climate thresholds have been identified (Task 3.2) CIRP can be applied to determine the impacts to interconnected CI Networks when climate thresholds are breached. These impacts can be linked to the likelihood component of risk e.g. either using the probability of appearance within climate data – or return periods.
- "Climate" approach as the driver, where existing observational data and/or model generated data for future climate regimes can be used:
    - As direct inputs to the CIRP in conducting a risk assessment and resiliency analysis;
    - As input data to estimate specific "return periods" of desired climate parameters which could then be fed into CIRP.

3.1 Policy objectives addressed by EU-CIRCLE

Table 5. EU-CIRCLE policy objectives
Primary relevance to WP: horizontally all project activities

The EU-CIRCLE analysis of CI climate resilience will provide guidance for potential users of the project's final products (frameworks, CIRP) to perform policy specific analysis and assessments. These will be user specified but introduced in the CIRP modelling environment in a simple and efficient way. EU-CIRCLE shall introduce new capabilities (i.e. policy assessments and risk/resiliency analyses) for the CI stakeholder community by allowing them to use different and diverse modelling solutions and services in a standardized environment. The partners aim to provide a tool which is customisable and enables the introduction of custom-made data as inputs to the CIRP analysis that will support regional, national and cross-border climate resilience and adaptation assessments.

CIRP, the mechanism for delivering the above objective, will provide authoring tools to define the logic of CI interdependencies, a clearly defined plug-in mechanism where new algorithms/analyses can be added anywhere along the analysis workflow enabling scientists to create new end-to-end analyses or to enhance existing analyses, modelling of various hazards and impacts on CIs, and mechanisms to develop risk reduction strategies and assessment of adaptation measures that minimize their impact on societies. CIRP will provide a web-based modelling environment where multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner.

In order to design the logic of CI interdependencies, and process components (as explained in section 4.2.8) in terms of functional flow blog diagrams, a clearly defined plug-in mechanism where new algorithms/analyses can be added anywhere along the analysis workflow enabling scientists to create new end-to-end analyses or to enhance existing analyses, modelling various hazards impacts on CIs, and mechanisms to develop risk reduction strategies and implementation plans for adaptation strategies that minimize their impact on societies. Modularity and extensibility to support the evolution of tools and capabilities as fast as research evolves is one of the main CIRP design goals. The design of CIRP will be based on the outcomes of all previous WPs

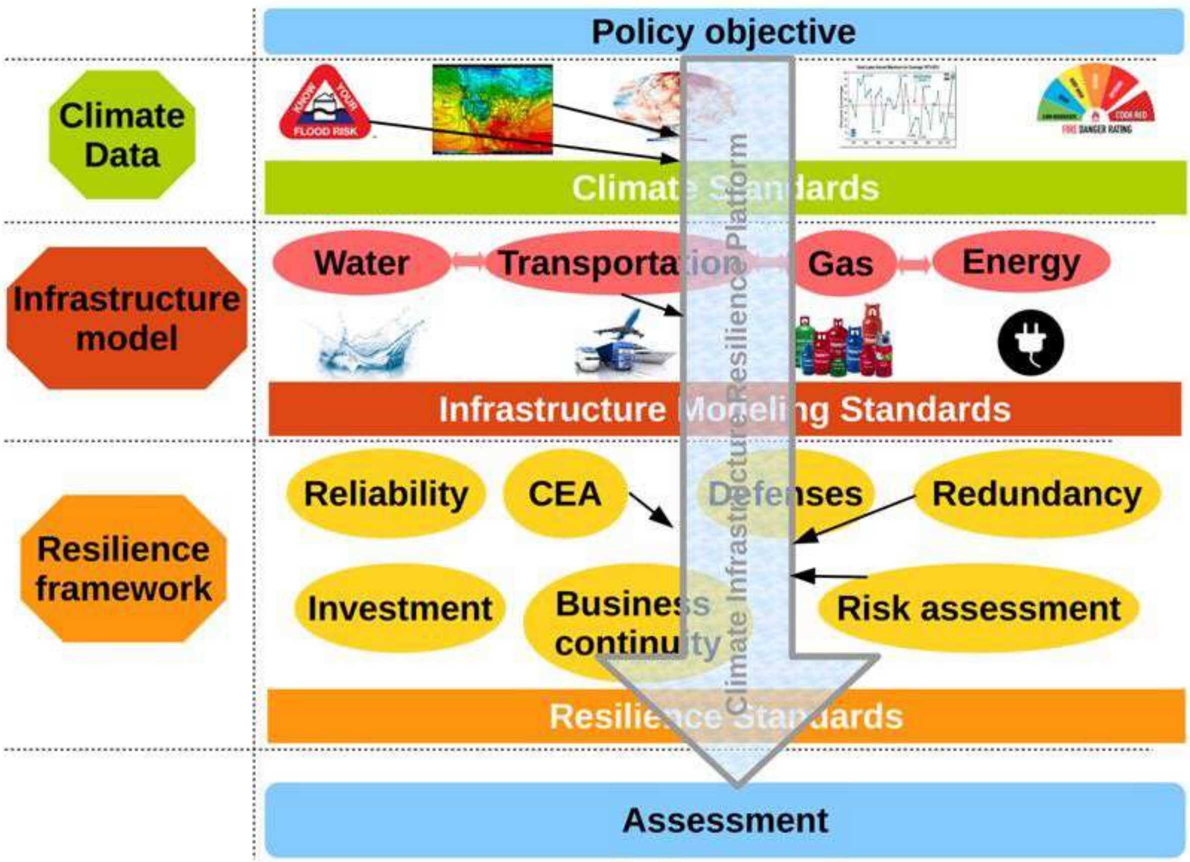

Figure 4- CIRP policy question development

Ultimately, CIRP users will have the simulation capability to scientifically respond to a large number of policy inquiries, as described below.

In the following text:

- C could be any of the infrastructures related to EU-CIRCLE – section 4.2 (energy, transportation, water, etc.). The analysis could include an entire CI network / sector formed of many independently operated infrastructures within a region of interest.
- R could be any location of interest for conducting the analysis; i.e. municipality, region(s) or country(ies), neighboring regions, cross-border
- H corresponds to climatic parameters and hazards within the scope of the EU-CIRCLE – section 4.3

Policy questions:

- How exposed is the C infrastructure of region R to a specific hazard H?
  - How exposed is the transportation network of Attica region, Greece to forest fires?
- How exposed is the infrastructure sector of region R to a specific hazard H?
  - How exposed is the energy sector of Attica region to heat waves?
- What is the current risk level of infrastructure C in region R, due to climate hazard C, and how is risk estimate anticipated to change in the future Y years?
  - What is the current risk level of water infrastructure in Attica region, due to extreme precipitation events, and how is risk estimate anticipated to change in the future 30 years?
- Which asset of infrastructure C is most vulnerable to extreme events, including impacts to interconnected infrastructures' assets?
  - Which asset of the water infrastructure is most vulnerable to extreme events, including impacts to interconnected infrastructures' assets?
- What is the most damaging climate hazard in region R? how is this attributed to its constitutional elements (society, economy, etc)?
  - What is the most damaging climate hazard in Attica region? How damages are attributed to its constitutional elements (society, economy, etc)?
- Which asset of infrastructure C is most critical to the societal continuity within a region R?
  - Which asset of energy infrastructure in Attica region is most critical to the societal continuity?
- How resilient is the C infrastructure to a specific climate hazard H; which could be estimated through the introduction and analysis of suitable resilience indices and metrics
  - How resilient is the health sector to heat waves, and how to quantify this value;
- How the holistic multi-risk due to climate drivers & hazards may be assessed for the CI sector / network / region
- Which is the optimal adaptation measure for infrastructure C (e.g. energy) under a list of potential alternatives? Is the same adaptation measure also beneficial for other climate hazards?
- How to minimize the impacts of the cascading effects stemming from infrastructure C to the interconnected ones, for a specific climate hazard H
  - How to minimize the impacts of cascading effects that are originated from electricity networks to the interconnected ones, for flooding events.
- What are the optimal climate thresholds for infrastructure C that if changed will increase resilience? What is the desired level of change for these thresholds? And how are these related to investment costs?
- How would an investment change the resilience of a specific infrastructure?
- How would an investment in a specific infrastructure C modify the resilience of a region?
- How will the infrastructure C risk / resilience dynamics change in the coming decades?
- Perform a cost benefit analysis (comparison) of different adaptation / investment alternatives.
- What is the optimal "time recovery objective" for a specific asset of infrastructure C, to maximize business continuity of the infrastructure.

These serve to highlight the wealth of different analyses that could be conducted with the aid and guidance of the EU-CIRCLE project.

3.2 Time scales involved

Table 6. EU-CIRCLE time-scales
Primary relevance to WP: WP2,WP3,WP4

A critical question within the scope of the project is the definition of the time-scales for conducting any of the policy analyses described above. It is a very central issue to EU-CIRCLE and is directly related to the data needed to be introduced and processed within CIRP. The following should be considered:

- Large infrastructures have usually a lifespan in the order of decades, and investment decisions therefore influence future generations' wellbeing.
- During the lifespan of infrastructures, there is a need for substantial efforts to address the concerns of aging. The fragility of vital infrastructure carries substantial consequences when such systems are stressed by major natural disasters, which are forecast to become both more frequent and more severe.

Current design philosophy of infrastructures is very much based on a standardized approach which has the presumption of a design life and a well-defined perspective on adverse events, e.g. according to [11] forest fires, ground movements, storms, hurricanes, cold & heat waves and drought have been identified as hazards pertaining to structural standards. Most of these calculations are based on expected probabilities within the assumed design life of the structure, which varies by code and country:

- EUROCODE gives the design life for temporary structures as 10 years, agricultural buildings as 30 years, common structures as 50 years, and monumental structures as 100 years [12]
- Australian Building Codes Board lists building design life as 15 years for short, 50 years for normal, and 100 years for long [13]
- UFC 1-200-01, General Building Requirements, describes as permanent facilities expected to serve for 25 years or more [14]

According to presentations made in the 2nd project meeting by the Cyprus Civil Defence, in their National Risk Assessment Plan, three different time periods are taken into account: 2020, 2050, 2080.

The timescale involved may also be linked to the expected annualised probability of an event (return period), frequently used as an indicator value for expected probability of occurrence. As a numerical example, the value of 0.5% annual probability is translated as an event occurring 1 in 200 years, which is a higher value of appearance than a 1 in 1000 (0.1%) annual probability event. This concept is also related to the likelihood (section 4.4) component of risk resulting in the "cumulative probabilities" of an infrastructure being exposed to a predefined event, and therefore directly linked to the design standard. As a numerical example, for any infrastructure asset with a 100 year design life, there is a 63% cumulative probability of seeing the 100 year snowfall, which is a high enough probability that this event should be considered in the design phase.

4 EU-CIRCLE generic process

This section introduces a "business process" type of analysis for describing and assessing the resilience of interconnected and interdependent critical infrastructures to climate change. It is directly linked, as described in the following sections, to associated WPs and Tasks within the EU-CIRCLE DoA. Historical analysis (D1.2 of EU-CIRCLE[4]), lessons learned and documented expert opinions (D1.4 of EU-CIRCLE[5]) have demonstrated how complex such dependencies are to identify, assess, in order to design an optimal adaptation strategy which will address impacts related to climate change.

According to current policy best practices [15], [16], [17], [18], [19] a climate change risk assessment usually considers (i) the possible threats that can emerge from an extreme event; (ii) the likelihood of an event occurring; and (iii) the consequences of the event. A climate change risk assessment provides information that allows a CI operator to manage risks, which can be achieved by changing the state of the system to reduce vulnerability, improve resilience and lessen potential climate impacts [20]. Owing to the diverse nature of infrastructures located within a region, current analyses, modelling and assessments have treated each infrastructure sector as separate and discrete. However every individual critical infrastructure relies on one or more infrastructure sectors to maintain functionality, making it a large scale complex system. Further adding to this complexity, is the variety of climatic parameters, the variety of infrastructure lifespans and the interaction of CI with human and physical systems. CI dependencies, interdependencies and interconnections increase the complexity of analysing all the constitutional elements in a unified, interoperable and coordinated method. As a result, domino effects can cascade far beyond a region of interest and can cross national boundaries.

Climate change has been recognised as a threat multiplier [21] extending the impacts of climate hazards, potentially creating new & amplifying existing interdependencies amongst critical infrastructures. A climate change risk & resilience assessment that does not address CI interconnections, and the possible loss or creation of interconnections, could lead to the miscalculation of risks. EU-CIRCLE aspires to devise a holistic framework for providing concrete understanding and assessment of cross-sector dependencies, interdependencies and cascading effects, thus contributing to the effective determination of CI climate resilience. In order to achieve this objective, [22] have identified two pathways:

1. Perform the analysis with a high level detailed analysis of the infrastructures systems (which have rarely been used for impact assessment of disruptions), and build on them to address the interdependencies between them
2. Perform an impact assessment analysis based on related models and methods mainly based on economic/financial theories with limitations on the representation of the details of the infrastructures' operation and functionality.

These two approaches are be suitable within specific and highly specialised decision-making contexts, their inherent limitations introduce large uncertainties in the derivation and interpretation of meaningful results. As an example to this assertion, in order to evaluate possible alternative mitigating options in case of a disruption to infrastructure services, it is necessary to incorporate sufficient level of detail in the assessment process, which traditional economic theory-based models have inherent limitations to account for them in the analysis.

EU-CIRCLE aspires to present a holistic methodological framework tightly linked to a highly-innovative simulation environment (the Climate Infrastructure Resilient Platform – CIRP / WP5) where:

i. Modelling of multi-tier climate related impacts on the infrastructure operation, economy and society at-large will be possible in a standardised manner;

[4] Forthcoming to M12 of the project
[5] Forthcoming to M12 of the project

ii. Collaborative assessment of resilience levels, preparedness options and adaptation opportunities of a specific region with CI "heterogeneous interconnected networks", where a loss or disruption in any infrastructure will most likely result is severe operational difficulties in the interconnected networks,

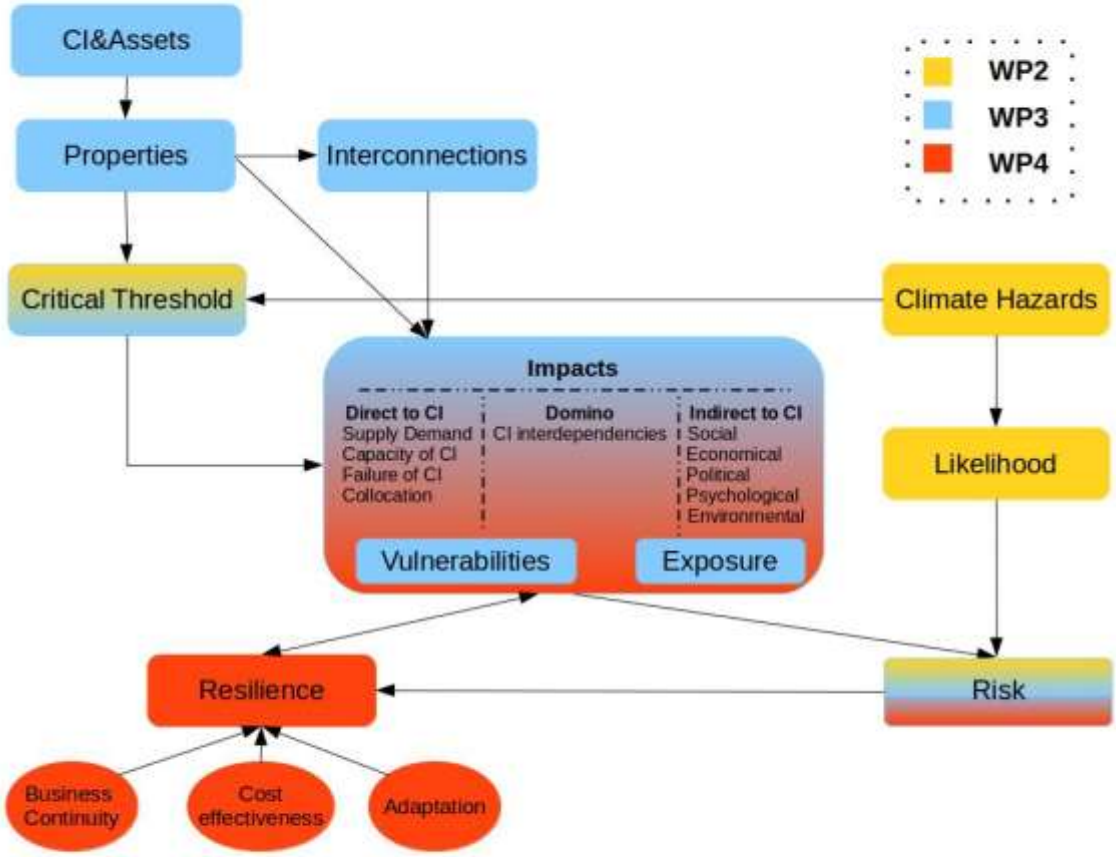

Figure 5- EU-CIRCLE framework high level description

The EU-CIRCLE proposed framework high-level description (Figure 5), is made up from the following generic components:

- Identification of interconnected CI. CI within the scope of EU-CIRCLE (section 4.2) will be identified, assessed and thoroughly analysed down to the level of detail which is needed in order to adequately respond to the policy objectives specified in Section 3 of this document. The properties/interconnections, and level of detail that describe each type of CI (and their interdependencies) will be based on their unique characteristics and attributes that may be useful to perform the subsequent analysis.
    a. Infrastructure characteristics that could be potentially modified under future climate regimes, or extreme climate event scenarios. This principle also applies to the different types of critical infrastructure interconnections and interdependencies.
    b. CI assets and components could be impacted by ageing, owning to assessment of future climate scenarios within EU-CIRCLE. This will introduce a change of the characteristics (attributes, properties and interdependencies) to be considered in the assessment of future responses of the infrastructures to climate regimes.

c. The introduction of mitigation / adaptation alternatives under specific policy objectives, shall be accounted (modelled within EU-CIRCLE) as “new infrastructure components” and compared against the baseline scenarios

- Hazards / threat assessment. Complementary to the CI, are the climate related drivers and hazards (section 4.3) which provide the probability of a specific (extreme) event or climate pattern to appear in the period under analysis within the specific policy objective. EU-CIRCLE envisaged analysis should be able to handle both historical / observational and model generated data, and should analyses require that the inputs these should be suitably transformed in order to (a) feed respective climate hazard models (e.g. flooding, forest fires, droughts) and (b) generate suitable inputs for risk assessment that include both the estimation of an incident occurring (likelihood) and driving the impact assessment models (e.g. estimate extremes, return periods).
- Criticality analysis. The objective of this component is to link climate parameters to the vulnerability of the different CI (including their assets) and introduce how their interdependencies could be affected by climate hazards. The determination of critical thresholds to CI sectors, linked to their probability of appearance in the future, could provide validated scientific inputs for making the most effective options when designing / adapting CI to future climate conditions.
- Impact assessment. The EU-CIRCLE resiliency framework is based upon the consequence based modelling approach, where different models are used in order to produce multi-tier impacts to the infrastructure operation in different climate conditions (section 4.4). EU-CIRCLE shall consider both impacts to infrastructure operation in future climate conditions and also impacts due to exceedance of the identified critical thresholds in the case of extreme events. The analysis should contain impacts due to changing climate parameters on:
    a. the supply / demand side of the infrastructure;
    b. the capacity functions of the infrastructure;
    c. the functional / operational level of the infrastructure.
- Risk assessment. Risk assessment of interconnected infrastructures to climate change is inherently linked to resilience, serving as it’s foundation (section 4.5). The implemented risk estimation and quantification approach within EU-CIRCLE will be able to support single and multi-risk assessment, allow for the prioritization between identified risks and introduce impacts from dependent, interdependent and interconnected infrastructures. Furthermore, the devised analysis should support the “translation” of the quantified risk under a specific policy objective analysis, to other existing risk estimations (e.g. in related literature, sectoral best practices, infrastructure studies) and national risk assessment studies.
- Resilience objective setting & analysis. Within EU-CIRCLE, resilience (section 4.6) is comprised of a set of different functions of the system under examination, all of which aim to ensure the continuity of normal system function. Therefore, within EU-CIRCLE different policy analyses with diverse multiple objectives will be supported and be prioritized where required. These include: risk identification and mitigation options, defence building, business continuity and restoration of services, and adaptation options in future conditions.
    a. The underlying economics / financial considerations in all the performed models within the proposed methodological framework will be an inherent part of the EU-CIRCLE. This assessment could take the different forms including CAPEX, OPEX, maintenance, retrofitting, replacement, etc. costs either individually or introduced into cost-benefit / cost-efficiency analysis.
    b. EU-CIRCLE assessment introduces the temporal dynamics into the analysis, and also the associated resilience indices (Task 4.3). The basis behind this consideration is that

disruptive events are not static but dynamic in nature and that resiliency is related to the capability to defend and to recover in a timely manner.

4.1 Uncertainty modelling

Table 7. EU-CIRCLE uncertainty handling
Primary relevance to WP: WP2,WP3,WP4 (framework) & WP5 (CIRP)

The assessment of climate change impacts on specific infrastructures contains a high degree of uncertainty [23], [24], [25], [26],[27] which is partially related to:

- ✓ the climate data , and the level of detail or scale of current climate models for infrastructure analysis and assessment purposes, and/or the uncertainties in climate models themselves and their basic assumptions [28], [29],
- ✓ the high variability in the CI characteristics and modus of operations, which is directly related to the country, legal framework, cultural society and environmental conditions for which they are constructed and within which they operate,
- ✓ the impacts of climate change that are intertwined with socio-economic trends like demographic change, changes in technology, production patterns and lifestyles leading to altered infrastructure demand.

Effectively, mastering uncertainty requires, on the one side, an expansion of the knowledge base and to improve the information available and full realization that uncertainty about future climate change will remain. Thus EU-CIRCLE offers a working framework coupled with a modelling environment where experts from different scientific domains, and the CI community should collaborate in order to increase their mutual understanding of the interconnected infrastructure behaviour under extreme events or changing climate conditions [30],[31]. Better knowledge of the uncertainties introduced in the assessment of infrastructure resilience to climate change leads to more efficient communication of the infrastructure resilience to the related stakeholders' community and the society.

Uncertainty about future climate conditions will remain [32]. Therefore, CI community and stakeholders need to be aware that their actions are taken according to the most appropriate use of the available knowledge. EU-CIRCLE methodological framework and the proposed simulation environment / CIRP shall allow the development and implementation of robust solutions that would be effective and efficient under a range of different policy objectives and examined scenarios.

The inputs to the process (identified in Fig. 6 as an inbound /left pointing green arrow) should contain a determination of the uncertainty (also described in the process meta-data), that is propagated using different modelling alternatives (to be specified in WP3 & WP4) and introduced in CIRP in WP5, leading to the output of the uncertainty in the different components of the process (identified in Fig. 6 as an outbound /right pointing purple arrow).

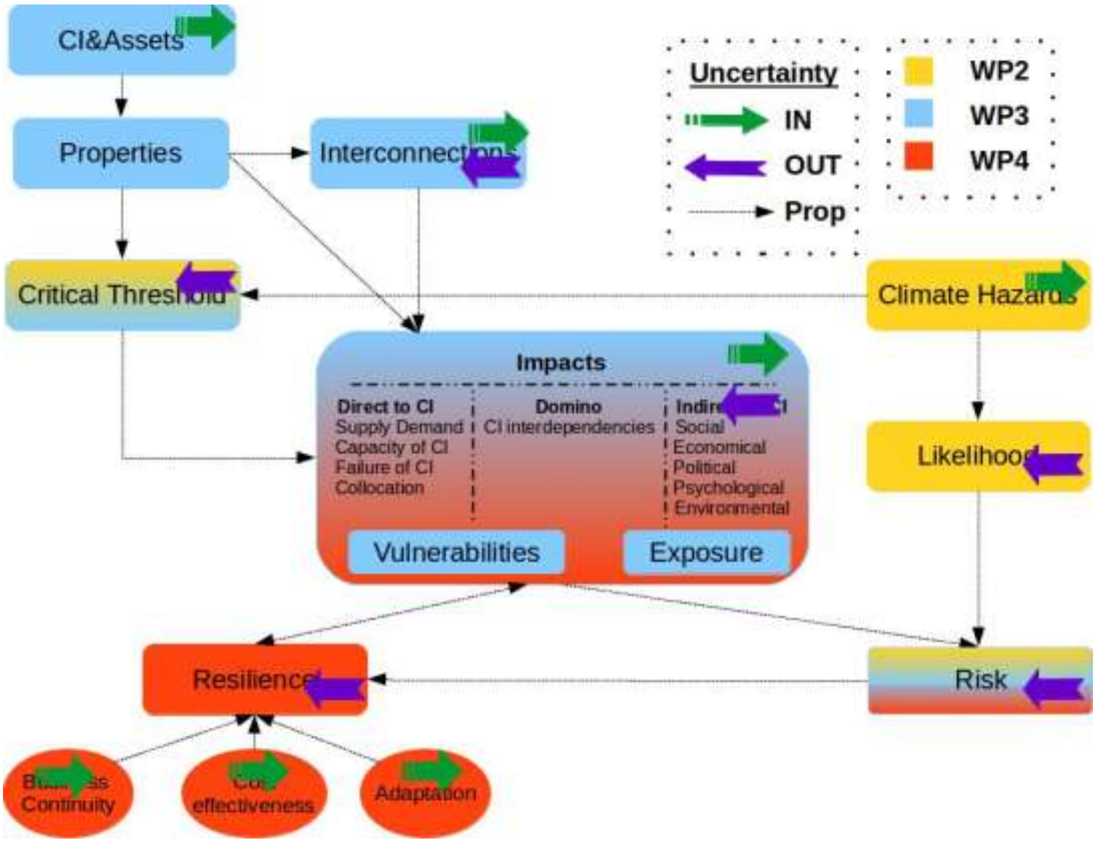

Figure 6- EU-CIRCLE framework with uncertainties

4.2 EU-CIRCLE infrastructure sectors

Table 8. EU-CIRCLE infrastructure sectors
Primary relevance to WP: WP3, Task 3.1, 3.2

According to national risk assessment plans, as summarised in [33],[34] the loss of critical infrastructure was identified as disaster risk by seven Member States: Czech Republic, Germany, Ireland, the Netherlands, Poland, Sweden, and the United Kingdom. Ireland's has included airports, ports, power and communications networks, transport networks and water supplies. Netherlands, Sweden and UK focused on power networks and water supplies. Denmark, Ireland, and UK consider the threat of potential damage to transport infrastructure and hubs looking at the economic impacts due to disruption in transport of goods and energy supplies.

This paragraph serves to identify the infrastructures' sectors that are of relevance to the EU-CIRCLE project, as decided on the 2nd project meeting in Cyprus. The selected sectors were identified according to:

- Directive 114/2008, on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection,
- SWD (2013) 13, Adapting infrastructure to climate change,
- SWD(2014) 134, Overview of natural and man-made disaster risks in the EU,

- SWD(2013) 318, On a new approach to the European Programme for Critical Infrastructure Protection Making European Critical Infrastructures more secure
- IPCC AR5 report, WGII on Impacts, Adaptation, and Vulnerability

WP3 of the project will perform an analysis of the infrastructure sectors described in this section, effectively contributing to:

- Identify, describe and model the properties and characteristics of CI and their constituent assets ; and their contribution and importance in the overall system's operation;
- Define how infrastructure assets are dependent and interdependent following the seminal approach of [35] distinguishing the connections as: physical, geographical, systemic and logical.

A hierarchical classification process will be applied to each type of infrastructure, so as to identify the different aspects that contribute to their operation, such as: demand; supply capacity; asset description (including structures, buildings & equipment, …) ; auxiliary assets; personnel; resources needed, flow of services/people/goods; transformation of goods/services/…, accessibility; capacity; input from / output to other infrastructures assets; economic and financial considerations of the operation; response plans; alternative services / replacements. This classification will be undertaken and presented in D3.1 Registry with CI assets, and interconnections due in M22.

An additional objective of the project, identified in "Task 3.2 Definition of climate related CI critical event parameters and CI exposure", will be to identify the climate related thresholds which have a significant impact on the CI. This work will be introduced in D3.2 Report of climate related critical event parameters due on M31.

4.2.1 Energy Sector

The energy sector faces multiple impacts from changing climate, with the most important ones identified as extreme weather events and increasing stress on water resources [36]–[40]. Greater resilience to climate change impacts will be essential to the viability of the energy sector and its ability to cost-effectively meet the rising energy demands driven by global economic and population growth. The energy sector is also pivotal to the analysis as it is virtually interconnected to every other sector of critical infrastructure and key to the well-being of modern societies. In the context of the electricity power system, strategic risk issues include a number of high-impact, low frequency events that could result in significant impact not only to the electricity sector but cascade to other critical infrastructures.

The main climate risks that the energy sector is exposed to include [36]:

- Extreme weather events that potentially affect energy production and delivery facilities which could cause supply disruptions.
- Changes in water availability will magnify challenges to energy production, e.g. hydropower, bioenergy as well as the operation of thermal power plants (fossil fuel and nuclear), which require water for cooling. This will be exacerbated by a combination of reduced water availability and a rising demand for water (e.g. growing population) which will limit available resources.
- Unusual patterns in temperatures which may change energy demand patterns.
- Sea level rise and storm surges could potentially affect coastal and off-shore energy infrastructures.

Which complement those identified in [41]:

- Magnification of business exposure to potential weather induced black outs
- Infrastructure loss due to extreme events – sometimes in extremely critical conjunction with high demand (cf. black out 2003 in Italy and Switzerland)
- Increased vulnerability in supplies – i.e. water intensive energy supply, higher variability of renewable installations produced power

Activities within EU-CIRCLE project take consideration of Nuclear Power Plants with a focus on water consumption and supply as well for the nuclear plants thermal efficiency and not In the event of a serious accident and their safety.

Nuclear plants as a whole withdraw and consume more water per unit of electricity produced than coal plants using similar cooling technologies as their operation is based on a lower temperature and lower turbine efficiency[6]. For the purposes of avoiding potentially catastrophic failure, these systems need to be kept running-cooling at all times, even when the plant is closed for refuelling, in order to keep the reactor core and used fuel rods cool. Since a large nuclear power plant that utilizes a cooling system may withdraw 3,028,330 m3 to 3,785,411 m3 of water a day, these plants are usually built next to rivers, lakes, or oceans, extreme weather events such as water unavailability or quality, might affect significantly the plants operation and efficiency.

4.2.2 Transportation

The impact of climate change and sea level rise on transport has received qualitative, but limited quantitative, focus in the published literature. The impact depends greatly on the climatic zone the infrastructure is in and how climate change will manifest itself [37]. The transportation sector [30] will be probably under threat from projected climate change. The rail sector has a high probability of being impacted by temperatures and extended heatwave periods especially for rail buckling, pavement deterioration and thermal comfort for passengers in vehicles. Extreme weather events will likely impact both the integrity of infrastructures and travel times due to interruptions and delays. Maritime transportation could be under threat from sea-level rise (harbours and other infrastructure).

Impacts of climate change to transportation have been identified in [42]:

- Projected increase in frequency and intensity of extreme weather could enhance negative impacts on the transport infrastructure, causing injuries and damages as well as economic losses.
- Potentially changing mobility patterns by EU citizens
- Transport modes could experience substantial increases in cost categories

4.2.3 Water - Sewage

Floods, Droughts and Water Scarcity have already affected large parts of the European Union and have an important impact on socio-economic developments [43]. River flows are projected to decrease in many parts of southern and south-eastern Europe and increase in northern and north-eastern Europe. Strong changes in seasonal run-offs are projected with lower flows in the summer and higher flows in the winter. Consequently, droughts and water stress will increase in the summer season, particularly for southern and south-eastern Europe [44].

[6] http://www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Water-Use-and-Nuclear-Power-Plants

According to [37] climate change will potentially impact with varying scale and intensity the water supply infrastructure and water demand. Economic impacts shall be substantial and will likely include flooding, scarcity, and cross-sectoral competition. Flooding can have major economic costs, both in term of impacts (capital destruction, disruption) and adaptation (construction, defensive investment). Water scarcity and competition for water—driven by institutional, economic, or social factors—may mean that water may not be in sufficient quantity or quality for some uses or locations

4.2.4 ICT Information & Communications

The information & communications sector has been relatively resilient to climate change and in normal operation less sensitive to climatic conditions. The sector itself is mainly prone to cascade effects from climate hazards [45] due to major dependencies on other sectors that include energy, transportation, water and logistics and thus is critical to the identification of dependencies and interdependencies of CI. Loss of telecommunication access during extreme weather events can inhibit disaster response and recovery efforts because of its critical role in providing logistical support for such activity [46]. Several assets of communications networks are at risk due to extreme winds and/or flooding [47].

4.2.5 Chemical Industry

According to industry reports, the key climatic changes relevant to the operation of chemical plants include the impacts of extreme events to off-shore and coastal infrastructures such as a rise in sea levels, increased wave heights and storm surges, flooding, and tropical storms and cyclones [48]. The impact of these risks for each project will be dependent on the location, facility type, facility design and expected life-time. Overall, the Chemical Sector's major dependencies on other sectors include transportation (ports, rail, and truck), energy, communications and waterways.

4.2.6 Health Sector

The health sector is critical in order to respond to the impacts of climate change and extreme events, and with this role has been considered as relevant to the EU-CIRCLE project. The health sector, as every other societal component, albeit to a lesser degree contributes to the production of greenhouse gases through the products and technologies it deploys, the energy and resources it consumes, the waste it generates and the buildings it constructs and operates. The promotion of the health sector resilience to climate change is a priority of the WHO [49]. Under the US Climate Change Toolkit[7], [50] it is perceived that health services must remain resilient against climate change hazards being available to communities and individuals in case of extreme weather events, even during (extended) infrastructure disturbances. Resilient health care organizations must anticipate extreme weather risks and transcend limitations of regional public policy, local development vulnerabilities, and community infrastructure challenges as they site, construct, and retrofit health care facilities.

[7] https://toolkit.climate.gov/

4.2.7 Governmental Services

Within EU-CIRCLE, the Government sector has been considered as a CI because it provides essential services through every infrastructure sector, following a similar approach to the UK [8]. These services are vital for state continuity and societal resilience throughout a potential disruption.

4.2.8 Interconnections between CI

Every critical infrastructure sector relies on one or more of the infrastructure sectors to maintain full functionality. There is substantial work placed into the assessment and analysis of dependencies and interdependencies between critical infrastructures [51]–[56]. This is a very young field of research; see for instance [57] for a comprehensive related review, which is mainly characterised by lack of data which hinders the development of a highly reliable model.

Within EU-CIRCLE "Task 3.3 CI interconnections" is devoted to the analysis of dependencies and interdependencies that crucially determine the interconnection between critical infrastructures residing in interconnected CI networks, and provide efficient modelling of the cascading effects that can result in domino effects. The interdependencies will be analysed with respect to the type of interconnection between them (physical, geographical, systems and logical) according to [58]. Specific emphasis will be placed on CI interdependencies that require actions beyond those needed for infrastructure restoration within the incident area. A clarification should occur at the point between:

- Dependent CI assets: A linkage or connection between two infrastructures, through which the state of one infrastructure asset influences or is correlated to the state of the other ; and
- Interdependent CI assets: are established through a bidirectional relationship between two infrastructures' assets through which the state of each infrastructure influences or is correlated to the state of the other. More generally, two infrastructures are interdependent when each is dependent on the other.

Should we not have something here on the fact that these interdependencies mean that we now often talk about emergent complex infra-systems, which is even more complex.

4.3 Climate parameters

Table 9. EU-CIRCLE climate parameters
Primary relevance to WP: WP2

Within EU-CIRCLE, climate parameters are the driving force behind the conducted analysis. The developed framework will leverage the vast amount of existing knowledge generated up to-date in the climate research domain. It will place primary emphasis on the processing/transformation of existing climate information to be suitable for supporting the policy objectives (Section 3). Furthermore, EU-CIRCLE shall provide all necessary arrangements and interfaces so that existing climate information is ingested into the CIRP (Task 2.3). Of specific interest to the scope of the project is the processing of uncertainty of climate data according to the provisions identified in section 4.1.

The climate information pertinent to the objectives of EU-CIRCLE will feed into the following components of the EU-CIRCLE generic framework (Figure 5)

- Provide an estimation of the likelihood of the climate induced risks to infrastructures,
- Contribute to the identification of the climate critical infrastructure thresholds and to the overall assessment of the vulnerability of interconnected CI to climate risks.

Based on the discussions at the 2nd project workshop, climate change related effects have been divided into (Table 10) two different categories:

1. Climate drivers, which are the direct output of simulation models (GCM/RCM, seasonal forecasting model) and observation networks
2. Climate hazards, which are direct consequence of climate drivers, are modelled using post-processing algorithms of the climate drivers and new simulation models from climate simulation models.

Table 10. EU-CIRCLE climate parameters and their interconnections

Climate drivers	Climate hazards
Temperature	Heat waves, cold snaps
Precipitation (rain / snowfall) - humidity	Floods
Winds	Forest Fires
Cloud / fog	Droughts
Solar radiation	Earth movement caused by climate drivers such as rain (landslide, erosion, avalanches)
Sea level rise	
Ice , frost	
Strom surges, waves	

Within EU-CIRCLE the following will not be considered:

- Air pollution, as there is no defining documentation that it has an impact on the functionality and integrity of critical infrastructures.
    - However, air pollution and emission of greenhouse gases has been considered as an environmental impact of CI (section 4.4.1)
- Emissions from volcanic ashes and dust from the Saharan desert
- Epidemics and impacts from population growth of insects and endogenous species & invasion of non-indigenous species etc. whose impacts are magnified due to climate change.

4.3.1 The 1.5 degree scenario

The UNFCCC Decision -/COP.21 on the adoption of the Paris Agreement: "Invites the Intergovernmental Panel on Climate Change to provide a special report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways[8] [59]. In light of this the EU-CIRCLE has been invited, alongside on-going and recently concluded EU-funded projects relevant to this objective, to identify upfront how they may be able to contribute – through peer-reviewed publications - to the challenge of delivering a solid report on 1.5 °C impacts and pathways.

EU-CIRCLE will do a considerable effort to align its activities with this call by the EC to assess the impacts of the 1.5 degree scenario on Europe's infrastructure, and more specifically, on the interdependent and interconnected systems of the five envisaged case studies. Some initial elements of this approach are described in the following lines:

- The climate priority scenario will be based on the RCP2.6 scenario [59], [60], (Fig. 6) which assumes that global annual GHG emissions (measured in CO2-equivalents) peak between 2010-2020, with emissions declining afterwards. This scenario assumes a projected increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 to be in the ranges derived from the concentration-driven CMIP5 model simulations, that is, 0.3°C to 1.7°C (RCP2.6).
    - A second scenario to be implemented will be the RCP4.5 scenario , where total radiative forcing is stabilized before 2100 by employment of a range of technologies and strategies for reducing greenhouse gas emissions [61]–[63]. For this realization, only a small number of models verified the 1.5 degree below the pre-industrial era (Fig. 7) and thus shall be considered as a low priority scenario within EU-CIRCLE.
- Some of the key elements of the shared socioeconomic pathway (SSP) used to derive the RCP2.6 scenario could be implemented within the CIRP for the examined scenario[9][10]. A detailed assessment of the changes portrayed in the SSP will be performed and elements introduced in the CIRP (WP6). Elements to be examined include changes in the land use / land cover data, population data, fuel mix, transportation patterns, but a more detailed analysis will be elaborated.
- The RCP2.6 scenario, will be downscaled to local / regional climate simulation, using data provided by the consortium within WP2, and those from other European initiatives (e.g. CORDEX[11][12] and the Climate4impact[13] portals)
- The CIRP will be employed to determine the impacts of the climate scenario on the examined infrastructure assets and compare the difference in the respective metrics (section 4&5) against the present conditions.

[8] http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/
[9] http://sos.noaa.gov/Datasets/dataset.php?id=436
[10] http://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=welcome
[11] http://www.cordex.org/
[12] http://www.euro-cordex.net/
[13] http://climate4impact.eu/impactportal/general/index.jsp

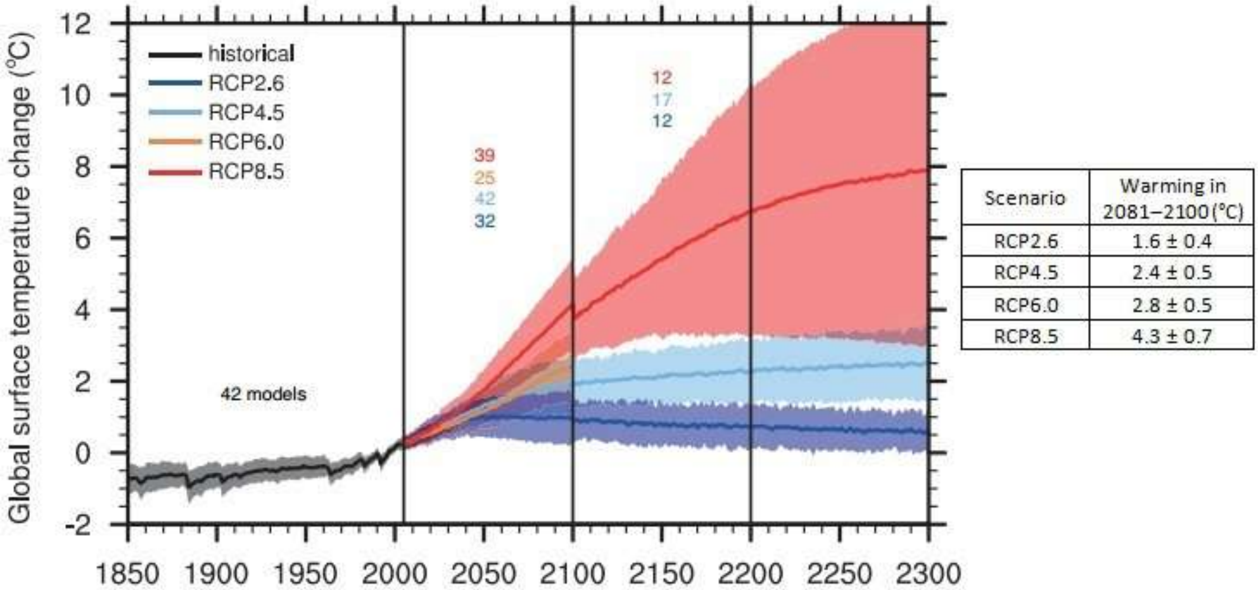

Figure 7- Global temperatures under RCP2.6 & RCP8.5 { Figure SPM.7 | CMIP5 multi-model simulated time series from 1950 to 2100 for (a) change in global annual mean surface temperature relative to 1986–2005 [28]}

Table SPM.2 | Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005. {12.4; Table 12.2, Table 13.5}

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range[c]	Mean	*Likely* range[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8

Figure 8- Projected change in global mean surface air temperature and global mean sea level rise for the mid and laye 21st century relative to the reference period of 1986-2005 [28]

4.4 Impacts

Table 11. EU-CIRCLE climate change impacts on CI
Primary relevance to WP: WP3, Task 3.4

According to EU documents [64] the impacts of climate change could be multi-dimensional and lead to cascade and domino effects. Impacts to CI vary considerably according to location, geophysical risk exposure, adaptive capacity and resilience and level of regional economic development. EEA [29] acknowledges that the increased frequency of extreme natural hazards such as floods, storms and forest fires could also induce natech accidents and industrial accidents resulting from these events.

<u>The key requirement for assessing the multi-dimensional impacts of CI are to be in compliant with the requirements as identified in key EU related policy documents addressed below</u>. However, these set the

minimum impacts of climate change to interconnected critical infrastructures and within the EU-CIRCLE, the list of potential impacts will be extended to include all potential impacts documented in related literature review (and presented in D1.2 State of the art review and taxonomy of existing knowledge), expert opinion (e.g. personal interviews & consolidation workshop on M12) and partner's subject matter expertise. A more detail analysis of the impacts will be presented in D3.4 Holistic CI Climate Hazard risk assessment framework due on M12, and the related models used within EU-CIRCLE will be presented on D3.3 Inventory of CI impact assessment models for climate hazards due on M32.

- ✓ National Risk Assessment Plans [11], accounting for the following parameters:
  - o Human impacts (number of affected people) are the number of deaths, the number of severely injured or ill people, and the number of permanently displaced people.
  - o Economic and environmental impacts are the sum of the total costs induced costs of cure including costs of environmental restoration and other environmental costs (or environmental damage)
  - o Political/social impacts may include categories such as public outrage and anxiety, encroachment of the territory, infringement of the international position, violation of the democratic system, and social psychological impact, and other factors considered important which cannot be measured in single units.
- ✓ EPCIP programme [65] where cross-cutting criteria have been identified as:
  - o casualties criterion (assessed in terms of the potential number of fatalities or injuries),
  - o economic effects criterion (assessed in terms of the significance of economic loss and/or degradation of products or services; including potential environmental effects);
  - o public effects criterion (assessed in terms of the impact on public confidence, physical suffering and disruption of daily life; including the loss of essential services).

Within EU-CIRCLE the impacts of climate hazards to interconnected infrastructures are associated with two discrete types of impacts:

1. Direct impacts to the operation of the infrastructure
2. Indirect impacts, related to the externalities of the CI operation, also including the societal costs

4.4.1 Direct impacts

Table 12. EU-CIRCLE Direct impacts to CI
Primary relevance to WP: WP3, Task 3.4

The direct impacts to the critical infrastructures due to climate change will be identified using a variety of criteria accounting for changes in the critical infrastructure properties in both "normal" state of operation and also due to extreme events. Thus the specific list of impacts will include:

a. Changes in the provision of CI "services and products" to the society,

- o Changes in requested demand (of CI services and products) from the society and economic actors using the CI in order to fulfil their goals (e.g. electricity and water demand)
- o Impacts in the production supply of the requested services/products of the infrastructure to the society (e.g. renewable energy production, production efficiency of power plants)
- o Changes in CI capacity (e.g. electricity transmission lines due to temperature)

b. Partial or total failure of the infrastructures due to extreme events

- o Casualties, including human losses and injuries
- o Economic cost, accounting for all components of the CI operation, repair, maintenance, replacement
- o Environmental impacts, to the water, soil and air emissions (including greenhouse gases and priority pollutants). The latter will be related to the climate change contribution of the infrastructures.
- o Business continuity and contingency actions that includes the business continuity planning (i.e., long-term strategy) and the disaster recovery planning (i.e., near- and mid-term strategies), including replacement services and availability of resources to keep operation at a minimum level.
- o Responses capacity, such as number of units and time needed to resolve an incident.
- o Social & Psychological, including the daily disruption, psychological impacts, possible political consequences, etc,

c. Domino effects

- o How climate parameters could contribute, strengthen, modify CI assets' dependencies and interdependencies

d. Domino effects

- o Due to CI generic interconnections (as described in section 4.2.8)

4.4.2 Indirect impacts

Table 13. EU-CIRCLE indirect impacts
Primary relevance to WP: WP3, Task 3.4

As CI are the backbones of modern societies, issues related to their operation below minimal thresholds could lead to social impacts: related to the daily lives and well-being of citizens and the economic sectors that utilise the services/products of critical infrastructures. The analysis will include the society as a whole, and societal landmarks such as cultural heritage, and other critical elements of the society such as schools.

4.5 Risk assessment

Table 14. EU-CIRCLE risk assessment methodologies

Primary relevance to WP: WP3, Task 3.4

Risk assessment of critical infrastructures to climate hazards is one of the core objectives of EU-CIRCLE and lies at the beginning of the resilience framework (section 4.6). Within EU-CIRCLE risk will be quantified using methodological approaches contributed by partners, taking into consideration the elements identified previously. The framework will be introduced in D3.4 Holistic CI climate risk assessment framework V1.0 due on M12, and will be validated by subject matter experts, outside to the consortium, at the Consolidation workshop (Task 1.4 / M12).

An important asset of the proposed work within Task 3.4 will be to efficiently introduce methods for analysing and modeling uncertainty in all aspects of the proposed methodological approach, including representations at all stages of the analysis from the infrastructure 2nd order effects (social and economic impacts).

The main challenge that will be addressed within EU-CIRCLE is to provide a common ground where different risk assessment methodologies and modelling schemes, from the critical infrastructure and the natural hazards community could co-exist and interfere in a seamless manner. A harmonization and interoperability of the different risk assessment schemes into a single approach or alternatively the provision of "translating solutions" between different risk approaches will be a key outcome of EU-CIRCLE.

The minimum basis will be for the proposed risk assessment framework to be compatible with

- ✓ the National Risk Assessment, as identified in [11] and introduce specific elements of the ;
- ✓ Account for risk propagation for the dependent, interdependent critical infrastructures ;
- ✓ Be easily "translated" and adapted between the various methodological frameworks , that may be proposed by partner's and do exist in the critical infrastructure communities, such as Gas[14] [66], Energy [67] (Group, 2010) and transportation [68] ;
- ✓ International standards, e.g. ISO 31000 Risk Management.
- ✓ Support multi-hazard risk assessment and provide an understandable way of prioritizing risks, with user selected subjective criteria.

The methodological framework to be proposed by EU-CIRCLE should be adaptable to the scope and specific needs of the audience it addresses (national authorities, CI community, research performing organizations) and the domain of applicability (asset level, infrastructure/system/network level, region of interest).

A common understanding and clear elucidation the final risk estimation should be present, to allow for the easy and direct interpretation of the derived risk metric. Although risk matrices in national risk assessment plans [69], have been set with quantified probability and impact on a 5x5 scale, these categories differ and could lead to different interpretations of severity of risks and, ultimately, different conclusions. According to this report some of the risk matrices are numbered 1 to 5 or use letters A to E – 1 and A being low probability/impact and 5 and E being high probability/impact, whereas other approaches use a specific terminology to express ranges. Additionally, within EU-CIRCLE the "acceptable level of risk" should be determined by users of the CIRP.

An important consideration when estimating risk is how to define the probability of appearance of climate hazards domain of interest which is related to the likelihood of risk. The concept of "return period" could be used to quantify climate parameters.

[14] http://www.gie.eu/index.php/publications

4.6 CI Resilience

Table 15. EU-CIRCLE resilience
Primary relevance to WP: WP4, Task 4.1, Task 4.2

According to the UNISDR terminology [15]Resilience has been defined as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. However, thus far resilience in the scope of climate change impact assessment studies and also the critical infrastructure protection community it has been fuzzily placed in a concrete and consolidated framework.

Resilience is a focal point of the EU-CIRCLE project, and according to several documents encompasses [70]–[75] activity to prevent, protect and prepare for impacts of climate change to interconnected critical infrastructures. A critical objective of the project will be to define the constituent components of resilience that fit its scope provisionally accounting for the following elements:

- Prevention – options to minimise exposure of CI to hazards, through the more efficient and effective understanding and prioritizing of potential risk and threats (WP2); identification of key infrastructures assets and adjustment of high-criticality assets that are vulnerable to climate hazards into less risk prone positions.
- Reducing potential impacts – enhance contingency planning and business continuity to ensure alternative supplies, reserve capacity, and / or rapid restoration of services (Task 4.2). This element could also examine different options such as building additional network connections, or by providing backup facilities to ensure continuity of services
- Optimization of the resources needed by CI to operate
- Adapting to climate risks – through the examination of the most cost benefit / cost efficient investment in protection and defences (Task 4.4) [76], [77];
- Account in this process of infrastructures dependencies on supply and distribution chains, and dependencies and interdependencies to other types of infrastructures on other infrastructure providers as an important element of business continuity.

The resilience framework of EU-CIRCLE will be produced in D4.1 EU-CIRCLE CI resilience framework to climate hazards _ first version, due on M12. It will be validated by subject matter experts, outside to the consortium at the Consolidation workshop (Task 1.4 / M12).

4.6.1 Resilience Metrics / Indicators

Table 16. EU-CIRCLE time-scales
Primary relevance to WP: WP4, Task 4.3

EU-CIRCLE has proposed within Task 4.3 to develop resilience indicators (metrics) to account for a quantifiable estimation of the interconnected CI systems risk and resilience estimations, as these were

[15] https://www.unisdr.org/we/inform/terminology

defined in the respective sections. The indicators will be developed in a multi-dimensional perspective allowing for the seamless quantification of the policy objectives identified in section 3.1 of this document. Resilience indicators are also an essential element for communicating to the EU-CIRCLE community and key stakeholders of the generated results, and also in the CI community in order to make informed based decisions on the CI optimal resilience strategies. According to [78],[79],[75] the development of resilience indicators should be aligned with the following EU-CIRCLE high level objectives:

- ✓ EU-CIRCLE developed resilience indicators must be useful for the required policy objective analysis, and should also match the requirements of the EU-CIRCLE stakeholder community.
- ✓ Provide an efficient means of comparison to different climate change mitigation & adaptation options. Furthermore, the same indicator, in order to be useful must be able to differentiate between the base (present) state of a system (interconnected CI) and to the envisaged options.
- ✓ Could be used for different time scales, accounting for the multi-year change of the CI characteristics and performance to changing climate patterns and be uniform in different spatial scales of application. The metrics should be considered “unchanges” as technology progresses and more complex analytic methods become feasible
- ✓ The devised set of resilience indicators support the framework both qualitatively and quantitatively, and critically reflect uncertainty in a well quantified perspective.

An indicative list (non-exhaustive) of indicators, which will be the product of D4.5 Resilience Indicators, due on M24, may be based on the following [80]–[83]

- ✓ Climate hazards and its likelihood metric (e.g. return period) in relation to CI thresholds
- ✓ CI performance under normal operation and climate change impacts,
- ✓ Impact related metrics
- ✓ Uncertainty of the derived results
- ✓ Resilience constitutents estimates and collective resilience indices
- ✓ Multiple Metrics combining any of the above

Within the project’s scope the following process will be followed in order to define the EU-CIRCLE pertinent indicators:

1. Extensive literature review of existing resilience indicators, clearly indicating their strength, weaknesses and potential suitability within the EU-CIRCLE project
2. Development of EU-CIRCLE pertinent resilience indicators, based on the risk components (likelihood & impacts), and resilience constituents
3. Validation of resilience indicators using SimICI , and potential improvement based on their performance characteristics
4. Introduction of the derived indicators in CIRP

5 CIRP high level design

Table 17. EU-CIRCLE CIRP
Primary relevance to WP: WP5

The EU-CIRCLE concept to assess the resilience of interconnected European Infrastructure to climate pressures includes the development and validation of the Climate Infrastructure Resilience Platform (CIRP). This will be established as an end-to-end modelling environment where new analyses can be added anywhere along the analysis workflow and where multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner providing an efficient "Best of Breeds" solution integrating existing modelling tools and data into a holistic resilience model in a standardised fashion. The platform will assess potential impacts due to climate hazards, provide monitoring through new resilience indicators and support cost-efficient adaptation measures [84]. The EU-CIRCLE framework, leveraging the vast amount of existing knowledge generated to date in the climate research domain, will provide an open-source web-based solution customizable to addressing community requirements, either in responding to short-term hazards and extreme weather events or in deriving the most effective long term adaptation measures.

CIRP should encompass "Big Data" management capabilities that will allow collection, processing, protection and appropriate sharing of information, as well as to develop the most effective models and simulations in case of disruption. CIRP can profit from the NCSRD High-Performance Computing (HPC) facility allowing for vastly superior computing power and memory requirements compared to standard desktop. Thus computationally intensive simulations should support more detailed description of the infrastructures and introduce higher volumes of climate data in the analsysis.

CIRP main objective is to become resilience management software, based on climate risk dynamic approach to critical infrastructure using the Consequence-based Management (CBM) methodology. This approach describes in concrete modelling approach the causes and consequences of the climate impacts to the CI characteristics, properties and performance. The proposed CIRP will be implemented through graphical user interface [GUI], with a simple straightforward installation, and amble capacity for users to introduce customized information and data. Its main characteristics are the following

- It should be able to support EU-CIRCLE's objectives, which are to analyze the resilience of multiple interconnected CI, for multiple climate hazards assessing multi-tier impacts and mitigation – adaptation alternative solutions. CIRP should support user generated analysis workflows responding to specific policy objectives
- It's fully modular allowing users to perform specific analysis using only specific components of the software, but also fully extensible that non-project partners to introduce i) new analyses can be added anywhere along a workflow, ii) new data types can be added
- Provide an efficient management and synchronization of different repositories, either of public domain, of cached locally (local repository)
- Introduce and compare "What-if scenarios", translating into the selection of models, data, interconnected CI description, multi-level damage assessment, adaptation / mitigation strategies, which are meaningful in conducting the policy objective and providing interpretation of the results into a "language" fully understood by the users of the systems and the EU-CIRCLE stakeholders

- The authoring and managing of policy scenarios, should be transformed to workflows can support the interconnection of analysis (input, output) graphically and being wrapped (via a File Descriptor) in a standardized way and controlled by the platform

CIRP will be using the basis of the ERGO open source modelling platform[16], by NCSA (National Center for Supercomputing Application – University of Illinois Urbana – Champaign). It was originally developed in a collaboration between the Mid America Earthquake (MAE) Center (multiple universities) and professional technology professionals from the National Center for Supercomputing Applications (NCSA) at the University of Illinois.

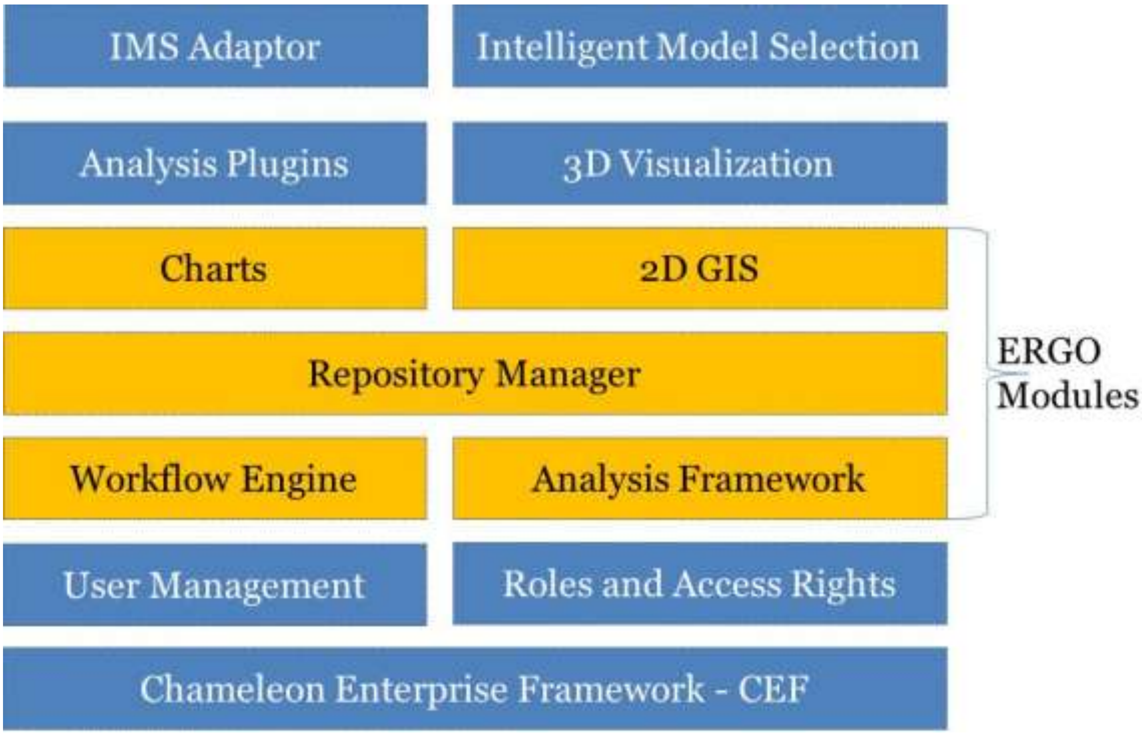

Figure 9. CIRP high level desgin

CIRP will be providing important extensions to Ergo platform including a number of features, such as:

- New types of infrastructures and link to societal functions
- Models for multiple hazards, as currently ERGO supports only earthquake and hurricanes
- Analysis and modeling of inter-dependent physical systems and non-technical systems that are essential for the recovery of a regional area (e.g. financial, social, healthcare, public safety, education, ...others)
- Link to external software for climate hazards (e.g. forest fires) and infrastructure operation models.

Ergo will be enhanced to incorporate a broader range of „community systems“, enabling interdepencies between these systems to be accounted for, in an integrated picture of the health or resiliency of a community.

[16] http://isda.ncsa.illinois.edu/drupal/software/ergo

6 Data management and formats

Table 18. EU-CIRCLE data management
Primary relevance to WP: WP2 (Task 2.4), WP3,WP4

One of the main challenges of EU-CIRCLE is to orchestrate a large amount of data diverse in nature and format into a single framework, where they will support the envisaged analysis (section 3.1) and seamless integration of model flow within CIRP (section 6). Thus EU-CIRCLE is facing with the most difficult challenge of introducing a common approach where different models would be interoperable, one accepting data from multiple different sources, including custom data from potential CIRP users.

The EU-CIRCLE approach is based on consistent data exchange and model application standards ensuring the seamless integration of the different components into a homogenized environment. EU-CIRLE will use extensively existing standards and common data formats into the different domains and when these are not available will propose an extension of existing state of knowledge and best practices. WP2, WP3 & WP4 have a task devoted to the presentation of utilised data into a common format.

WP2 (Task 2.4) will use data structures such as Open Geospatial Consortium[17] (OGC), CF (Climate and Forecast) metadata conventions[18], WMO-TD No. 1186[85] , FP7-CHARMe project climate data annotation[19], and so forth.

WP3 (Task 3.6) and WP4 (Task 4.6) due to the divergence of the typology of infrastructures several different approaches exist that includes Eurocodes [12], CEN Guide 4 "Guide for the inclusion of environmental aspects in product standards", PIEVC Protocol[20], OGC specific Working Group (e.g. E&U DWG), Common Information Model (CIM), developed by the electric power industry. For risk assessment OGC[6] and OASIS[21] and ACORD[22] data have been proposed, as is the JRC ongoing work disaster and loss data standard[23].

EU-CIRCLE is participating in the EU Open Research Data Pilot. The goal of Open Research Data Pilot is to make the research data generated by selected Horizon 2020 projects accessible with as few restrictions as possible, while at the same time protecting sensitive data from inappropriate access. EU-CIRCLE adopts those objectives and in addition to this, the datasets generated will follow the EU policy and JPI approach guidelines. Four types of datasets will be generated: infrastructure asset description and characteristics (including interconnections) data, climate data, climate impacts to infrastructures data, resilience / adaptation models and approaches data.

Moreover, part of EU-CIRCLE Data Management Plan is to make all deliverables freely available (at least, electronically) to anyone who wants a copy. However, we will use either a CC-BY or CC-0 license for all of our project products in order to ensure that they are shared with minimal restrictions, aside from attribution to the authors or creators. All user-generated data created by the public will remain the copyright and intellectual property of the data providers (the organisations or service providers) or data creators (the users) in compliance with the data providers own terms and conditions. The project will make

17 http://www.opengeospatial.org
18 http://cfconventions.org/
19 https://github.com/charme-project
20 http://pievc.ca
21 https://www.oasis-open.org
22 https://www.acord.org
23 http://drr.jrc.ec.europa.eu/Loss-Data

use of different possibilities for open access provision, depending upon what is most appropriate for the publications selected, the article itself and the partners that have produced the material.

In order to establish a common "language" between datasets from different sources, a standardization of format and metadata processes is under evaluation. The goal is to use already well-established data format and metadata processes, make enhancements or create a basis for new ones whereas standards don't exist or don't fill EU-CIRCLE project's requirements. A prevision concerning data loss is taking into account according to the Joint Research Centre technical recommendations.

7 SimICI & Validation studies

Table 19. EU-CIRCLE SimICI & Validation studies
Primary relevance to WP: WP6 & WP7

The generated scientific knowledge that will be introduced within CIRP will be progressively tested in order to ensure a) the highest possible scientific standards including the introduction of the uncertainties within this process and b) the generated results are meaningful and clearly interpretable for the EU-CIRCLE stakeholder community. CIRP will provide a web-based modeling environment where multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner.

EU-CIRCLE, within WP7 will create a reference virtual environment for assessing the resilience of infrastructures to climate pressures, termed as SimICI. It will effectively be a controlled environment for Simulating Interconnected (Critical) Infrastructures, Climate Hazards, Effects, and Risk/Impact Propagation through dynamic orchestration of models. During the CIPR development phases, SimICI shall serve as a testbed for all developments, integrations, and evaluations performed, whereas after the project's completion SimICI shall be a legacy providing a further exploitation mechanism. Under this prim, it serves as the primary enabler for an outreach programme intended to maximise awareness and to increase exploitation and ecosystem-led extension in the open-source community. SimICI will serve the objective to provide maximum flexibility and extensibility leveraging open-source software and open-standards/data formats to maximise the application space. Build within SimICI the outputs of the EU-CIRCLE project in relation to Climate Hazards, Critical Infrastructure Assets and Networks, and Critical Infrastructure Resilience and provide a clearly defined Application Programming Interface (API) through which SimICI may be integrated with the core EU-CIRCLE Framework.

Different scenarios and policy objectives, will encompass a build phase (in which the required information such as infrastructure, assets, impact models, climate data, and other requirements are constructed for use in SimICI) and a test phase (in which the constructed items are tested for operational suitability). The reference data that will be collected will be abstract information about the city of Athens, augmented to include any potential CI and assets required to have a full representation of a reference CI "network of networks".

Additionally, five case studies will be used to validate the project's outcome and generated knowledge. The validation will include

- Qualitative assessment, based upon a dedicated questionnaire where all aspects of the proposed resilience framework, web-based application, results obtained, future exploitation will be analysed and introduced
- Quantitative assessment using the derived Resilience Indicators and a series of Key Performance Indicators to evaluate (a) EU-CIRCLE functionality and user-friendliness, (b) introduced web-based tools to assess climate hazards resilience of CI, (c) added value of the results, (d) future exploitation.

The foreseen case studies will be implemented in the following generic manner, each one organised by local partner(s) that has the overall responsibility. Depending on the case study and the CI involved and climate hazard, different competent partners will be involved introducing suitable tools, systems and components to CIRP. The following order is proposed, but subject to local conditions:

1. Setup – scenario specification design,
2. Model implementation and customization,

3. Case Study Description and preparation,
4. Data collection,
5. National training course (1 day before case study), where participants to the case study will be have the opportunity to familiarize with CIRP,
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,
8. Summary Report,

In summary the proposed case studies are:

- ✓ Case Study 1: Extreme Drought and forest fire impact on electricity and transport networks, concerning a cross border event between France and Italy,
- ✓ Case Study 2: Storm and Sea Surge at a Baltic Sea Port , Gdynia Poland
- ✓ Case Study 3: Coastal Flooding (surface water, highway, sewer and watercourse flooding) across Torbay, UK
- ✓ Case Study 4: International Event, concerning disasters impact to local community and test findings of research in Disaster Resilience to Climate Change in Bangladesh
- ✓ Case Study 5: Rapid Winter Flooding (melting ice, narrow mountain streams, flooding) around Dresden, Germany

8 Dissemination and exploitation

Table 20. EU-CIRCLE dissemination and exploitation plan
Primary relevance to WP: WP8

The EU-CIRCLE dissemination and exploitation approach has been extensively described in D8.1 Dissemination and Exploitation plan, submitted on M3 of the project, and will be updated at M12, and M24. The dissemination is organised at the overall project level, as well as at the level of the individual participating organizations (section 5 of D8.1). The plan defines the following at the EU-CIRCLE consortium level, as well as at the level of the individual partners:

- Audience and target groups, which includes i) CI community (owners/operators), National Critical Infrastructures Authorities, Civil Protection authorities at regional, national and EU level, Members of the related scientific community,
- The main message(s) and objective(s) for dissemination adhere to the following general rules:
    - The message is designed to meet the needs of the target audience ("clarity").
    - The message is designed to be consistent, truthful and credible ("transparency").
    - The message highlights the main EU-CIRCLE objectives ("identity").
- The type of communication channels which include the project's website, online tools and social media and print media, scientific publications and other broadcasting media.
- The expected results of the dissemination and exploitation activities, as measured through Key Performance Indicators (KPI's)

At the project level a website (http://www.eu-circle.eu/wp/), social media presence, bi-annual newsletters and scientific (open access) papers and conference proceedings will be available. A final workshop will bring together all results and data from the project. To stimulate the Dissemination and the mutual contact between the Partner organisations on the issue of dissemination a Communication team has been established, in which all Partners are being represented.

EU-CIRCLE exploitation phase will progress in parallel with WP5 and WP7 development, where the optimal exploitation model of the project's generated will be defined. It is a goal of the project's partners that the developed framework, standards and methodologies will be accessible to the stakeholders who have a confirmed interest in creating customised and innovative solutions. As such, EU-CIRCLE will significantly add to the existing pool of knowledge and increase choice in the market. The design and architecture of EU-CIRCLE outputs, emphasising transparency and greater flexibility, will allow potential users to develop fully customised solutions linked to relevant CI data and properties, to define and implement customised impact assessment models, and to use climate / weather data on demand. A consolidated exploitation model will be provided by the consortium D8.10 EU-CIRCLE exploitation models, due on M27

9 Conclusions

This Deliverable introduced the strategic context of the EU-CIRCLE project, through the definition of the specific elements that constitute the project and its interconnections and dependencies. The document proposed a set of high-level objectives that will align the critical infrastructure (CI) community (CI owners / operators, security planners and personnel, competent authorities at the national / regional / local levels) with the climatology and natural hazards community.

These objectives that were amalgamated from partners meeting, structured and unstructured discussion with subject matter experts will be core to the project during its life-time and include the following:

i. Shifting from traditional CI prevention / protection concepts to resilience, introducing the element of a holistic security framework for multiple time horizons.
ii. Development of a common understanding between the critical infrastructure and natural hazards communities, as a first step towards the "all hazards approach" as identified in the European Critical Infrastructures Directive 2008/114/EC.
iii. Introduction of the concept of "resiliency – by – design" when assessing the potential impacts of climate pressures to newly planned infrastructures.
iv. Introduction of a complete modelling framework of interdependent and interconnected infrastructures, taking into account CI changes due to climate parameters for example changes to the supply/demand of the CI, the capability of the infrastructures, the potential for reduced or complete inoperability due to extreme events etc.
v. Participation in the EC activities on the 1.5 degree climate scenario related impacts and pathways.

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