This Project has received funding from European Comission by means of Horizon 2020, The EU Framework Programme for Research and Innovation, under Grant Agreement no. 700174

WWW.RESCCUE.EU

#resccueEU

RESCCUE

RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

D5.2 Report on methodologies for the selection of resilience strategies

Date: 30 April 2019

RESCCUE - RESilience to cope with Climate Change in Urban arEas - a multisectorial approach focusing on water

Grant Agreement no.700174.

DELIVERABLE NUMBER:	D5.2
DELIVERABLE NAME:	Report on methodologies for the selection of resilience strategies
WP:	WP5
DELIVERY DUE DATE:	30/04/2019
ACTUAL DATE OF SUBMISSION:	30/04/2019
DISSEMINATION LEVEL:	Public
LEAD BENEFICIARY:	Cetaqua
MAIN AUTHOR:	Martínez-Gomariz, Eduardo
CONTRIBUTOR(S):	Guerrero Hidalga, María (CETaqua); Martínez, Montse (AQUATEC); Stevens, John (Bristol City Council); Almeida, Maria do Céu (LNEC); Cristina Pereira (LNEC); Morais, Marco (CML), Telhado, Maria João (CML); Silva, Inês (EDP); Duarte, Nuno (EDP); Pimentel, Nuno (AdTA); Alves, Rita (AdTA); Lopes, Ruth (HIDRA); Barreiro, João (HIDRA); Metelo, Inês (CML); Pacheco, Paula (CML); Lourenço, Ana Cristina (CML); Coelho, Luísa (CML)
INTERNAL REVIEWER:	Termes, Montserrat
EXTERNAL REVIEWER:	Velasco, Marc

Document history

DATE	VERSION	AUTHOR	COMMENTS
23/04/2018	v0	Martínez-Gomariz, Eduardo	Create document structure, introduction and background
18/03/2019	V1	Martínez-Gomariz, Eduardo	Embed workshops details for Barcelona

21/03/2019	V2	Guerrero-Hidalga, María	Embed methodology for prioritization of strategies
26/03/02018	V3	Martínez, Montse	Review
12/04/2019	V4	Cardoso, Maria Adriana; Almeida, Maria do Ceu	Embed Problem characterization and workshop details for Lisbon
29/04/2016	V9	Velasco, Marc and Termes, Montserrat	Final version after the inclusion of comments from the internal and external reviewers
30/04/2016	V11	Martínez-Gomariz, Eduardo and Guerrero-Hidalga, María	This version includes the corrections proposed by the external reviewers

RESCCUE
RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

1. **Changes with respect to the DoA**
   None

2. **Dissemination and uptake**
   Public (PU). The report is fully open and will be distributed through the web

3. **Short Summary of results (<250 words)**
   Deliverable D5.2 – "Report on methodologies for the selection of resilience strategies" provides two main outputs of the project: a methodology to effectively select adaptation strategies (implement them according to a prioritization), and a list of strategies for each case study (Lisbon, Barcelona and Bristol) obtained based on the project results and the problems characterization. The methodology proposed distinguishes between both urban services-oriented (identified in the RESCCUE project) and social-oriented (identified in existing plans) strategies. The first group is also included in the strategies list for each city and their origin is a City Council identification which focuses mainly the strategies on citizens' vulnerabilities directly. The second group is identified in RESCCUE according to the obtained results for both scales: detailed (i.e. sectorial models), and holistic (Hazur® assessment). Also a direct contribution from the tasks related to the Resilience Action Plan (RAP) development for each city has been undertaken in order to identify and fulfil the strategies list provided herein. Moreover, minutes of the workshops held in each city during the task 5.3 time period are presented in this report. The main aim of these workshops was to discuss about the possible strategies to be implemented in each city. Some conclusions about the methodology implementation and the strategies list identification are presented in the last section of this document.

4. **Evidence of accomplishment**
   The current state and needs regarding adaptation strategies for each city have been described. A web-based application was developed in order to facilitate the strategies collection.

RESCCUE
RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

Table of contents

RESCCUE
RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

Tables/Figures Summary

RESCCUE
RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

Executive Summary

The present Deliverable D5.2 presents the results obtained once carried out the task 5.3 of fifth Work Package (following WP5) regarding resilience and adaptation strategies ready for market uptake. The WP5 of RESCCUE project covers the development of a framework to promote resilience strategies, the creation of a measures database, **the establishment of a methodology to be able to compare all resilience strategies by prioritizing the measures depending on their cost and resilience effectiveness**, and all of this included within a module to be finally integrated into Hazur® platform.

During the time period of developing task 5.3, two workshops have been held in each research site (Lisbon, Barcelona and Bristol). The aim of these workshops was to agree about a proper methodology to prioritize strategies and also to identify a list of adaptation strategies needed according to the climate impacts that threaten the cities today and to be prepared for the future ones. Therefore, together with the minutes of the different workshops, this report describes the methodology of adaptation strategies prioritization that was agreed in the workshops, and also a comprehensive list of strategies is presented according to the problems characterization of each city.

The proposed methodology distinguishes between two approaches, one related to urban services-oriented strategies (identified through RESCCUE project), and another one focused on social-oriented strategies (identified in existing plans). The latter group is not the primary objective of RESCCUE project, however these strategies have been taken into consideration due to their importance for a city. The second group is also included in the strategies list for each city and their origin is a City Council identification to address citizens' vulnerabilities and welfare. The first group is identified in RESCCUE according to the obtained results for both scales: detailed (i.e. sectorial models), and holistic (Hazur® assessment). Moreover, a direct contribution from the tasks related to the Resilience Action Plan (RAP) development for each city has been undertaken in order to identify and fulfil the strategies list provided herein.

Both approaches are based on the three key variables entirely described in D5.1 (investment, city recovery time, and co-benefits). While the first category (urban services-oriented) is proposed to be assessed through a multiple-step method formed mainly by a cost effectiveness analysis (CEA) and a cost-benefit analysis (CBA), the one proposed for the second type of strategies (social-oriented) refers to a multi-criteria analysis. Furthermore, a description of the climate change-related problems for each city is included, as well as new strategies identified for each of them. They have been summarized in this document and further details have been provided in the strategies web-based platform developed in the framework of RESCCUE project.

This document is broken down into three main sections: prioritization methods of climate adaptation strategies, problem characterization and description of adaptation strategies, and local workshops. The first one offers a detailed description of the approach proposed herein to prioritize the selection of strategies, which will be a common procedure for the three research sites. Secondly, the individual problem characterization for the three cities will be presented and comprehensively described, which leads to the strategies identification. The proposed list of strategies are included also in this second section. During the development of the task, which leaded to the results described in this document, two workshops were held in each city in order to mainly discuss in depth regarding the identification of the needs of the

city in terms of climate adaptation. The summary of these workshops' conclusions can be found in the last section of this report.

1 Introduction and RESCCUE general framework

The present report corresponds to the deliverable D5.2 within the WP5 of the RESCCUE project. The project deals with climate change in urban areas, so that, with resilience and potential impacts of extreme events on urban services, such as transport, energy production, and water and energy distribution. The project provides a framework to enabling city resilience assessment, planning and management. RESCCUE assumes a significant importance in increasing urban resilience to a wide range of challenges, which can have physical, economic or social origin, being the natural ones, the threats of main concern in RESCCUE. In particular, this objective has to be achieved by implementing new tools and models, suitable for different kinds of city, characterized by several climate conditions and pressures. One of the most important contributions of the project is the analysis of the interrelations among the several urban services and the impacts that climate change will generate on each one. A particular relevance to effects of a failure in one sector and its consequences in terms of cascade effects has been taken into account.

The detailed knowledge of the behaviour of our urban systems during extreme climate events allowed the site characterization and the analysis of each urban service with special focus on their potential link with extreme climate phenomena.

On the other hand, the analysis of the behaviour and the response of strategic services and critical infrastructures with respect to specific pressures and drivers related to climate change has to be conducted through detailed models and software tools. The outputs of these sectorial models will be used to assess hazard, vulnerability and risk levels related to the pressures/drivers for current and future scenarios where **a set of adaptation strategies will be simulated and evaluated in terms of impacts reduction**. Afterwards, as a second step, the urban services interdependencies and the cascade effects due to failures caused by impacts of extreme climate events can be studied.

This second step in RESCCUE is treated by two different approaches characterized by a different level of detail:

1. Detailed approach: Advanced models and tools to describe specific cascading effects produced by extreme climate events on several urban services are developed. Then, the analysis of certain impact events could be achieved via the use of loosely coupled models and tools (integrated models).
2. Holistic approach: using the resilience assessment tool (HAZUR), the relations and the cascading effects among the different urban services can be analysed.

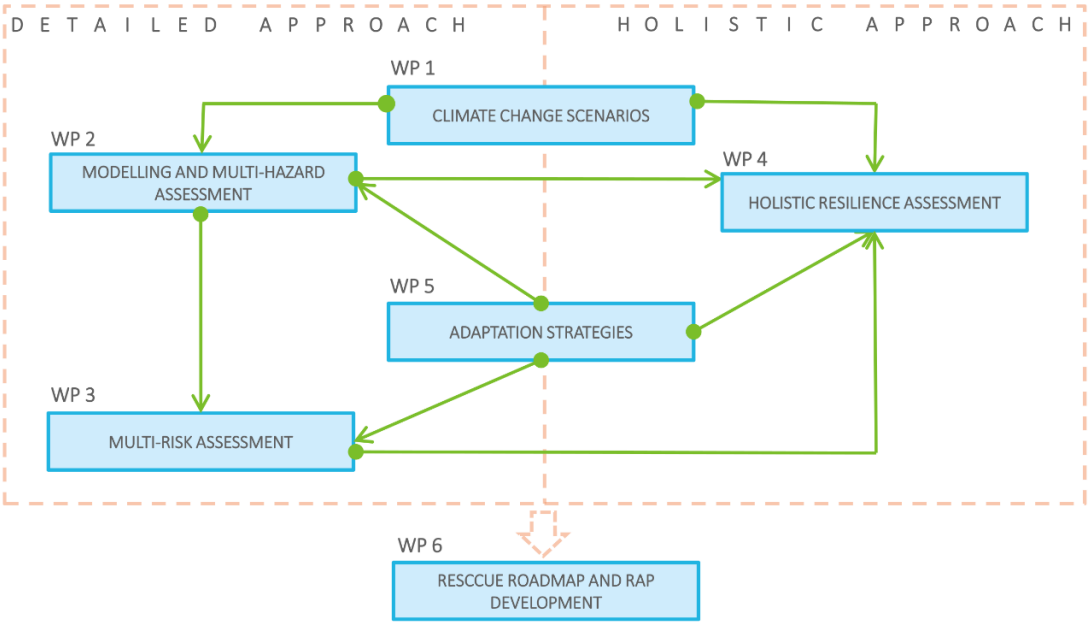


Figure 1. Summary of RESCCUE framework

Once the resilience of the cities is assessed through this double approach (i.e. detailed and holistic), adaptation strategies have to be identified in order to enhance the current urban resilience. However, not all the identified strategies can be implemented for several reasons (e.g. budget availability, etc.) and not all of them may be implemented simultaneously. It is clear that all the defined strategies have to be gathered within a resilience plan, but also a manner to prioritize them, before applying them, should be proposed in order to establish an implementation timeline. Therefore, an adequate method to evaluate their efficiency has to be proposed. These methodologies will ease the selection of adequate and efficient strategies to decision-makers. Evaluating the effectiveness of adaptation strategies in cities is the key towards adapting the cities to the impacts of climate change.

In the previous report, corresponding to the deliverable D5.1 of the RESCCUE project, the multisectorial resilience strategies framework was described. Moreover, a web-based platform which gathers adaptation measures and allows users to create strategies was developed. Within this framework three key variables (i.e. city recovery time reduction, co-benefits and strategies' estimated cost) were proposed to make decisions for the adaptation strategies selection. However, the way to relate them within a complete methodology in order to prioritize adaptation strategies was out of its scope.

1. Recovery time reduction

2. Co-benefits

3. Strategies estimated cost

The present report (D5.2) aims at providing methodologies to assist the prioritization in the selection of adaptation strategies and measures, based on the analysis of the three key variables proposed in the framework. An effective selection means an adequate prioritization of those strategies identified after the problem characterization for a target city.

The structure of this document is broken down into three main sections: prioritization methods of climate adaptation strategies, problem characterization and description of adaptation strategies, and local workshops. The first one offers a detailed description of the approach proposed herein to prioritize the selection of strategies, which will be a common procedure for the three research sites. Secondly, the individual problem characterization for the three cities will be presented and comprehensively described, which leads to the strategies identification. The proposed list of strategies are included also in this second section. During the development of the task, which led to the results described in this document, two workshops were held in each city in order to mainly discuss in depth regarding the identification of the needs of the city in terms of climate adaptation. The summary of these workshops' conclusions can be found in the last section of this report.

Note that a glossary with the terminology utilized in this report, which includes also other deliverables' terms, can be checked in the Annex A1.

2 Prioritization methods of climate adaptation strategies

2.1 Introduction

The implementation of adaptation strategies is normally limited by factors such as **capital and labour constraints** and subject to political momentum; therefore a prioritization assessment should be performed in order to **select the most suitable set of measures** for each city under a changing climate scenario. There are multiple criteria to rank available options to facilitate decision-making processes. The preferred methods usually imply **consideration of efficiency, economic, social and environmental indicators**.

A sensible approach begins by recognising that there are several viable strategies with different contributions to society, thus there are multiple combinations for effective adaptation. Some of them will be more efficient minimizing the risks associated to social issues (e.g. protect the most vulnerable people), while others will cover those related to urban services (e.g. secure electricity supply). It is also relevant to address the variety of information available for every strategy and measure, as well as the effects of those in society and the economy.

As can be seen from Figure 2, in the RESCCUE framework, strategies arise from three main sources: 1) the Hazur assessment; 2) Resilience Assessment Framework (RAF) and; 3) the sectorial models. In addition, cities are welcomed to propose new strategies, such as Barcelona City Council, that counts with a Climate Plan with several ideas to protect its citizens, with a clear social approach. The RAF is the outcome of the WP6, where a framework is developed to assess the resilience of the strategies coming from both Hazur® and the sectorial models. As depicted in Figure 2, a risks re-assessment will be conducted in WP3 by considering the implementation of the strategies into the sectorial models, and the reduction of these risks will be an essential factor in order to prioritize strategies, together with the recovery time reduction calculated through a post-strategies Hazur® assessment.

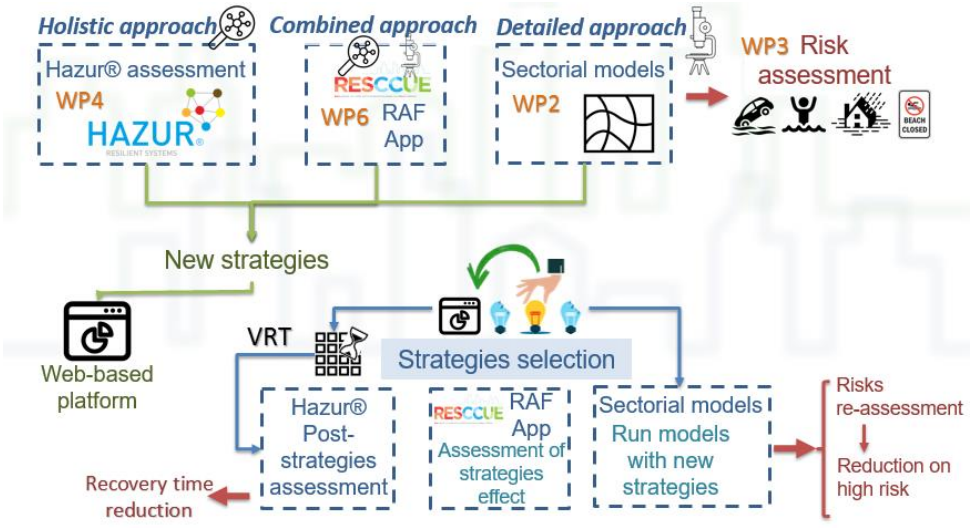


Figure 2 Outline of resilience strategies framework

The present prioritization exercise is built upon the above, together with the deliverable 5.1, *Multisectorial Resilience Strategies Framework and Strategies Database Development* (D5.1), in which the aim of improving urban services' resilience was defined. The **focus of strategies analysis was on the water cycle, power, mobility, waste and telecommunications sectors of urban areas**. The complex interlinks between sectors and cascading effects were considered when developing the framework. These are represented in the **Hazur®** tool, which **assesses the resilience of a site's urban services in terms of vulnerability and risks** towards extreme climate events, with and without adaptation strategies.

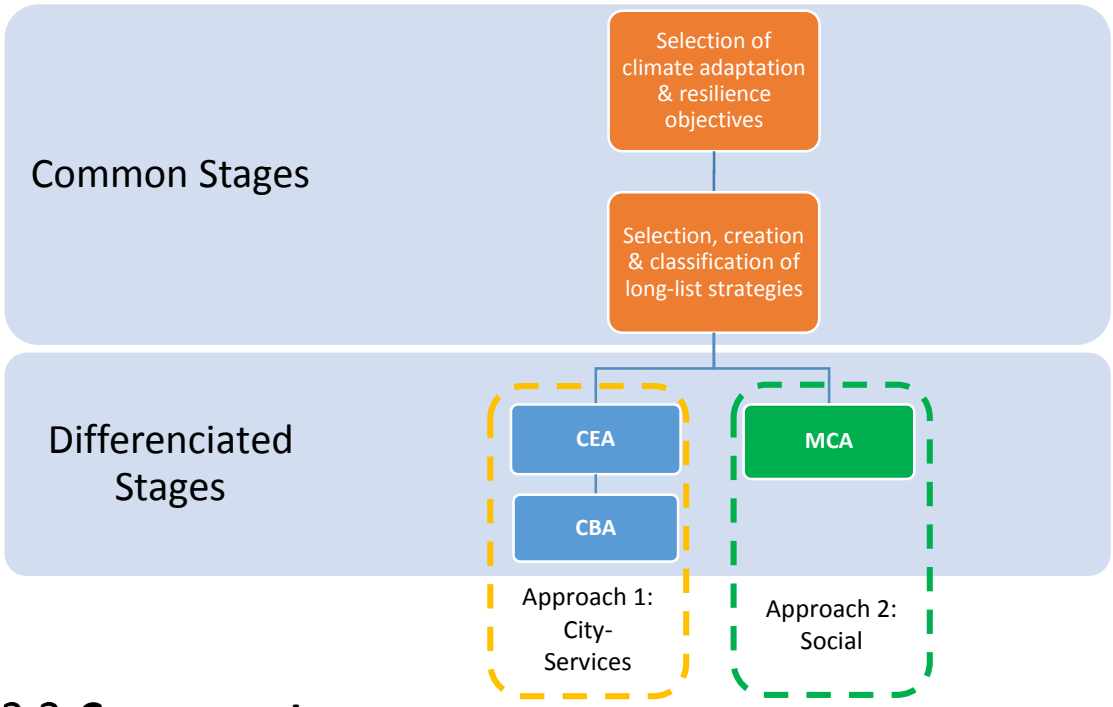
The application of the "*what if matrix*" in Hazur® identifies interdependences between services and infrastructures, existing redundancies, impacts and consequences into the urban system. It helps to understand the changes that a potential adaptation strategy might have in a given city. In order to leverage in its development for RESCCUE, we present the prioritization strategy based on the outputs obtained from Hazur®. Regarding transferability of the method, the processes can be easily adjusted to carry out the prioritization using only the web-based platform of RESCCUE, although the results are expected to be less accurate.

In order to align objectives with the RESCCUE project, the focus of prioritization will be on **adaptation strategies that secure functioning of urban services under future impacts caused by climate change**. The proposed methodology distinguishes between those strategies oriented towards improving the urban services (and consequently improving local welfare) and those which have a social improvement focus. The main differentiator is whether they affect or not the cities' utilities performance. Nevertheless, all strategies ultimately benefit society, although the distinction lays on whether social improvement is the main goal of the strategy or it is a co-benefit (Ürge-Vorsatz *et al.*, 2014) (see Glossary in Annex A1).

The present section proposes a combined prioritization methodology, which gives the necessary flexibility to analysts[1], in order to allow ranking adaptation strategies with different levels of information and objectives. The tools and inputs used in the prioritization exercise are from the RESCCUE project.

This prioritization method consists in a sequence of steps to gradually shortlist the most suitable options, based on two possible approaches: 1) a combination of Cost-Effectiveness Analysis (CEA), Co-benefits ranking, and Environmental Cost-Benefit Analysis (CBA), for the urban services-oriented strategies – main focus of RESCCUE, and 2) a Multi-Criteria Analysis (MCA) for social-oriented strategies. The first stages are common for both methods.

[1] Analyst, in this context, refers to the person applying the methodology in the case study.



2.2 Common stages

In the first place, **stakeholders must identify and define their specific objectives** within the broad spectrum of climate change adaptation and resilience. To do so, it is recommended that the interested parties review the list of adaptation strategies and measures, available in the RESCCUE web-based platform[2].

Once the objectives are defined, a **preliminary long-list of strategies**, comprised by sets of measures, should be proposed. A list of measures was specifically developed for the three cities involved in the project – Barcelona, Bristol and Lisbon, thus they might not be suitable for cities with different characteristics or objectives. In this case, it is recommended to introduce new adaptation measures in the web-platform. This process consists on: introducing the estimated implementation costs, the co-benefits scores and the estimated variation of recovery time matrix (VRTM) of each urban service (e.g. water storage) after an impact (e.g. flood). These measures should be grouped by strategies.

The risks and vulnerabilities of the city should be assessed with Hazur® with and without the considered strategies. This will provide a resilience metric, which will allow to see the variation of the recovery time of urban services, compared to the situation without adaptation strategies.

At this point, it is recommended that analysts classify the aim of the strategy, which can be **urban service-oriented** (which aim is structural or physical) **or social** (which aim is non-structural or institutional). A further classification is by typology of **measure,** as summarized in Table 1. These measures can be organized by: 1) Engineered and built environment; 2)

[2] Please visit: https://resccue2.herokuapp.com/ Username: user@resccue.com Password: User1234

Technological; 3) Ecosystem-based; 4) Educational; 5) Informational; 6) Behavioural; 7) Economic; 8) Laws and regulations and 9) Government policies and programs.

Table 1 Classification of strategies and measures proposed

Type of Strategy (aim)	Type of measure	Example
Urban Services Improvements (Structural/physical)	**Engineered and built environment**	Improve surface drainage system
	Technological	Self-healing (ICT system)
	Ecosystem-based	Green roofs/SUDS
Social Improvements (Non-Structural/Institutional)	**Educational**	Training, exercises and education to transfer scientific and operational knowledge to practitioners
	Informational	Improve the public information provided in pollution episodes and warnings of new risks
	Behavioural	Foster water saving on a municipal level
	Economic Non-Structural/Institutional	Locate and characterize climate risk areas
	Laws and regulations Non-Structural/Institutional	Tax incentives for housing energy improvements
	Government policies and programmes	Run publicity campaigns to encourage water savings on a domestic level

Once the strategies have been classified, analysts should follow the prioritization approach more convenient for the type of strategies under analysis, as it is presented in the following subsections.

It is worth remembering the framework established in D5.1, related to the assessment of a city's resilience state. The resilience metric (i.e. how long an infrastructure will remain inoperative after being damaged by an impact or downtime), the co-benefits and estimated cost of implementing strategies will be the three main variables to assist the Hazur® user (stakeholders or decision-makers) for the strategies selection (strategies effectiveness). The framework indicates that the initial resilience state for each research site is established in WP4 thanks to the resilience assessment in each city using Hazur®. The application of adaptation strategies should increase the city's resilience, thus, a post-strategies resilience state will also be assessed through Hazur® and these results will be useful to prioritize their implementation (Figure 2). Therefore, the prioritization approach is based significantly on information available to be used by analysts.

2.3 Approach 1: Prioritization Method for Urban Services-Oriented Strategies

2.3.1 Classification of measures

This methodology **focuses on the prioritization of strategies related to the improvement of urban services**. After the common steps are completed, the next phase is to **divide each strategy into two scenarios**, one containing the full set of measures, and a second scenario comprised by a subset of measures. The criterion options to create scenarios from subsets of strategies herein proposed are:

- Measures that are further technically developed
- Measures that are easier/more competitive to implement
- Measures that are already developed
- By type of measures (e.g. engineering, ecosystem-based, etc.)
- By type of strategy (structural and non-structural)

In table 2 an example is presented, where the scenarios (subsets of the strategy) are defined following the last criteria, the types of strategy, i.e. structural and non-structural.

In order to facilitate the understanding of the application of the methodology, this section presents a detailed process. However, it is up to the expert criteria in this step to further subdivide strategies or compare directly the strategies as they are.

Table 2 Example Box: Strategy, its associated measures and classification

Strategy Name: Flood Impacts Reduction in a Context of Climate Change			
Measure Name	**Measure type**	**Scenario (subset of strategy)**	
		Structural/physical	**Non-structural**
1. Improvements of surface drainage system (New inlets)	Engineered and built environment	✓	
2. Increase of sewer system capacity (I) (New pipes)	Engineered and built environment	✓	
3. Increase of sewer system capacity (II) (New storage tanks for flooding protection)	Engineered and built environment	✓	
4. SUDs (green roofs, infiltration trenches, detention basins for rural catchments)	Ecosystem-based	✓	✓
5. Real Time Control Systems	Government policies and programs	✓	✓

Strategy Name: Flood Impacts Reduction in a Context of Climate Change			
Measure Name	Measure type	Scenario (subset of strategy)	
		Structural/physical	Non-structural
6. Early Warning System	Government policies and programs	✓	✓
7. Ensure the stability of waste containers	Engineered and built environment	✓	
8. Self-healing	Technological	✓	✓

This classification allows a contrasting sets of measures, to further understand the impact and effectiveness at a more detailed level, which is relevant assuming budgetary and time constrains.

Considering the structure of the RESCCUE web-platform, in order to obtain the information necessary for analysis, new strategies should be created in the system with the selected subsets of measures, i.e. a new strategy per scenario. This process is uncomplicated, as it is just a duplication of the existing items.

2.3.2 Cost- Effectiveness Analysis and Co-benefits Rank

The second step involves the application of Cost-Effectiveness Analysis (CEA) and ranking the co-benefits for the sets of measures, so-named scenarios, described above. These inputs can be extracted from the RESCCUE web-based platform and Hazur®.

This step allows an initial prioritization, considering the efficiency (CEA) and the co-benefits associated to strategies. The indicators are measured in terms of the reduction of the city recovery time (through Hazur® assessment) and co-benefits averages. Thus, the result will be a list of scenarios with the cost per hour of reduced downtime and the associated improvements in social, economic and environmental aspects.

2.3.2.1 Cost-effectiveness analysis (CEA)

Cost-effectiveness analysis is used to compare and rank different options for achieving a given objective that is not measurable in monetary terms (RIVM, 2014). It does it by assessing alternatives in terms of the cost per unit of benefit delivered- e.g. cost per hour reduced of downtime. In this case, the general objective is to increase a city's resilience, but it should be defined more precisely- e.g. reduction of the recovery time of critical urban services in 50%. The indicator of efficiency is the percentage of reduction of recovery time[3], obtained from the assessment of the urban services and re-assessment of the same with the strategy, through

[3] In the case that the VRT matrix is not available or not sufficiently significant, analysts are encouraged to carry out a simplified CEA or least cost analysis, which consist in just ranking the scenarios by their estimated costs.

the *what-if* matrix in Hazur®. This exercise will provide the new recovery time of the city after implementation of the strategy.

The method consists in the following steps:

1. Define a relevant and clear objective – reduction of downtime of all critical urban services in 50%, 75% or 100%
2. Identify options for achieving the objective –scenarios previously defined
3. Identify the investment cost per scenario – available for each strategy at the RESCCUE web-platform
4. Obtain the efficiency indicator – percentage of variation of recovery time of a city's services (once again, it comes from re-assessment with the "*what if*" matrix in Hazur®)
5. Calculate the quotient of the cost and the total VRT of the scenario
6. Rank scenarios in terms of increasing unit costs

Table 3 Example Box: illustration of implementation of CEA, using the same strategy as in Table 2

No.	Scenario Description	Cost	VRT	CEA	Rank
1.1	All measures of strategy 1	5.000.000 €	3 h	1.666.667 €/h	#2
1.2	Non-structural measures (measures 5, 6, 7 & 8 of strategy 1)	1.000.000 €	2 h	500.000 €/h	#1

The idea behind the proposed scenario classification is to allow comparison of efficiency between the set of measures that theoretically involve more resources (structural) with those that are more readily available.

The simplicity of this method, allows a rapid implementation, although it is also its most relevant disadvantage. CEA does not consider externalities and does not take into account if the benefits of a strategy outweigh its costs. Therefore, it is suggested to use it as a complementary instrument for prioritization.

2.3.2.2 Co-benefits ranking

In parallel, the methodology proposes to rank the same scenarios considering the expected co-benefits they bear. This information should be available for all measures included in the RESCCUE platform, including the newly added by the interested city.

This additional ranking exercise is particularly attractive for case studies that have a large number of initial measures to assess, and a number of stakeholders with different priorities. It is recommended not to use it as the only prioritization technique.

The co-benefits are formed by economic, social and environmental factors, which contain a number of related indicators (see example box in

Table 4). The relative values (weights) support the decision-making process from a qualitative perspective (LSE, 2016).

Table 4 Example Box: co-benefits indicators and their assigned weights (W) for Scenario 1.1

Economic	W	Social	W	Environmental	W
Cost savings	10	Reduced mortality impacts	2	Improved air quality	0
Reduced energy losses	7	Reduced health impacts	10	Improved water quantity	3
Job creation	6	Reduced mortality from diseases	5	Reduced aquifer depletion	6
Possible reduction in prices	9	Enhanced public amenity	10	Reduced water pollution	9
Increased labour productivity	4	Reduced impacts on vulnerable groups	7	Reduced land contamination	7
Increased economic production	3	Reduced number of householder/business forced from home/ workplace	5	Improved biodiversity and ecosystems	7
Increased property values	7	Social inclusion	5	Maintained and increased green space	7
				Reduced environmental impacts through associated awareness	10
				Increased biodiversity and ecosystem services	6
				Effective/uninterrupted water collection and security	3
				Erosion control	8
Average weight	6.5	Average weight	5.6	Average weight	6

The process consist in the following steps:

1. Take the weights available in the RESCCUE web-platform, which have been proposed based on sectorial-experts judgement. As said before, the scenarios containing all measures will have the co-benefits already available; while the scenarios with only the non-structural measures will have to be created in the platform to make this information available.
2. Calculate the average of weights by type of co-benefit (i.e. economic, social and environmental). A template can be provided to facilitate this step.

2.3.2.3 Shortlist scenarios

From this double classification, analysts will be able to select the sets of measures considering both effectiveness and welfare indicators (i.e. co-benefits weights). In the example box 4 (Table 5) there is a suggestion of weights distribution to prioritize scenarios, but it is up to the analysts and decision-makers to decide the distribution criteria.

Table 5 Example Box: scenario ranking using the 2 criteria: CEA and Co-benefits

Proposed weights	35%		20%	20%	25%		
Scenario ID	CEA	Rank	Econ.	Social	Environ.	Co-ben rank	Final rank
1.1	1.666.667 €/h	#6	6.5	5.6	6	#5	#3
1.2	500.000 €/h	#4	3.2	2.5	3	#8	#1
2.1	2.500.000 €/h	#7	7.5	4	8	#4	#4
2.2	100.000 €/h	#1	5	3	7	#6	#5
3.1	15.000.000 €/h	#8	9	10	9.5	#1	#6
3.2	600.000 €/h	#5	7	7.5	8	#2	#7
4.1	300.000 €/h	#2	6.5	9	7	#3	#8
4.2	400.000 €/h	#3	5	4	4	#7	#2

In a context where several measures are under consideration (Barcelona's case study has more than 30 urban services-related measures) with different levels of information available, it requires many resources to perform a comprehensive Cost-Benefit Analysis for each one, and it is likely that the results are not accurate. Therefore, a prior CEA is recommended in these cases. On the contrary, if the number of measures to evaluate is not too high and there are sufficient data inputs, it is recommended to perform directly a CBA, as it is a more thorough decision-making tool.

In addition to classify and doing the previous prioritization exercise, this "multi-faceted approach" tool helps to discriminate strategies or measures under a pre-set threshold. It can be either a cost or welfare contribution frontier, set by the decision-maker budget and/or objectives. Therefore, the proposed methodology leaves the decision of the number of scenarios to assess in the next step, the CBA, although it is recommend that it is not larger than four.

2.3.3 Cost-Benefit Analysis (CBA)

Once the shortlisted scenarios are selected, the next step proposed is a **Cost-Benefit Analysis (CBA)**. CBA is an analytical tool for assessing the **economic advantages (benefits)** and **disadvantages (costs)** of an investment decision. Through this exercise, it is possible to assess the welfare change attributable to such investment (OECD, 2018).

It will provide a more detailed review of the expected outcomes of each scenario, by considering investment and operating costs (i.e. CAPEX and OPEX), as well as the benefits of implementation.

The process to carry out a comprehensive CBA can be defined as follows:

1. Definition of the **time horizon** – the RESCCUE project recommends to use the next 50 years period after strategies implementation
2. Definition of the **baseline scenario.** The aim is to identify what would happen without any adaptation, also known as "business as usual". it is important to include:
    a. Risks[4] posed by climate change in urban services during the period of study. It includes the expected physical damage when an extreme weather event hits the city
    b. Recovery time of urban services in baseline (reference) scenario
    c. Costs of recovery from extreme weather events and disaster management (direct and indirect damages caused by the event)
3. **Definition of adaptation scenarios**:
    a. Variation of risk level after implementation, including new expected damages
    b. Variation of recovery time of services after applying each of the strategies selected
    c. Estimation of CAPEX and OPEX of the measures implementation
4. **Assessment of the variation in the expected damage level for each scenario** considered, compared to the baseline scenario:
    a. The benefits are assessed in terms of:
        i. Avoided costs for a reduction of damage and risks in the city due to implementation of adaptation measures
            1. Direct and Indirect damages avoided
            2. Risks avoided (e.g. ratio between the high-risk area before and after applying the strategy)
        ii. Positive externalities (e.g. environmental or social improvements)
    b. The costs are:
        i. Expenses from strategies implementation (initial investment and operation costs)
        ii. Negative externalities (e.g. environmental or social losses)
5. Selection of the **discount rate** in order to adjust future (or past, if it is an ex-post analysis) monetary values to present values. Taking into account that these are public projects over a medium term context, and climate change is being considered, it is recommended to use a low discount rate, in the range of 1-4%, and if possible, calculate a declining discount rate (OECD, 2018). However, as this is a very

[4] Risk is understood as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

controversial topic in environmental economics[5], therefore it is suggested to carry out a sensitivity analysis to understand how it affects the results.

6. Selection of the **decision rule**. The results of the CBA can be ranked by different criterion, to provide a valuable tool that is able cover the different requirements of decision-makers. While some seek to implement the strategy with higher total value, others prefer to prioritize by:
    a. Net present value (NPV): the difference between the discounted total social benefits and costs, expressed in monetary terms.

$$NPV = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \frac{S_2}{(1+i)^2} + \cdots + \frac{S_n}{(1+i)^n}$$

    Where i is the discount rate, n the time horizon and S the cash flow. The decision criteria follows:

    NPV > 0 → the project generates net benefits
    NPV < 0 → the project does not generate net benefits

    b. **Economic Rate of Return (ERR):** the rate (i) that produces a zero value for the NPV**.** The decision criteria follows:
    i > ERR → the project is not economically feasible
    i < ERR → the project is economically feasible

    c. **B/C Ratio:** the ratio between discounted economic benefits and costs

7. **Sensitivity analysis**. It is recommended to estimate the decision rule with different parameters such as the discount rate or the time horizon to understand how the results respond to the changes

8. **Ranking alternatives according to the chosen criteria**

The present methodology proposes to not include only economic valuation methods for known attribute changes, such as the reduction on flood damages and energy consumption changes. But it is recommended to include as well economic valuation of other externalities which monetary estimation are feasible. For example, improved air or water quality are nowadays uncomplicated to monetize through **benefit transfer** method. In summary, this method consist in using the results obtained in previous valuation studies, and adapt the estimates to the new context (OECD, 2018). If this option appears unfeasible, co-benefits ranking is already available from previous step (2.3.2.2) and can be included together with CBA results as support information.

Cost-Benefit Analysis is a valuable instrument to rank alternative projects and it is widely used in policy-making. As a drawback, it requires considerable amounts of information regarding financial, economic and technical details for each scenario. In addition, results could be

[5] To support decision-making, OECD (2018) and EC (2014) references are a trusted source of information.

subject to tampering. Therefore, the application of the methodology should be done by experts.

2.4 Approach 2: Prioritization Method for Social-Oriented Strategies

The strategies oriented to meet social objectives will be ranked using a Multi-Criteria Analysis (MCA). This method was selected for its emphasis on the judgement of the decision-making team, and the ability to prioritize without monetary values (Department for Communities and Local Government, 2009). Decision-makers are responsible for establishing concrete objectives and criteria, estimating relative importance weights and scores, and to some extent, in judging the contribution of each option to each performance criterion.

The main advantage is the capability to tailor the prioritization exercise to the specific needs of each location. In addition, it offers an exclusion criteria without the need to estimate monetary values. On the other hand, the subjectivity that stakeholders can bring to the judging exercise must be handled with care (European Commission, 2017).

Following the previous methods, the proposed MCA methodology is based on the framework developed in D5.1, thus the inputs are accessible from the context of RESCCUE: investment costs, co-benefits scores and resilience level, which is measured by the recovery time of urban services after an extreme weather event (e.g. hours to recover from a power cut after a flooding event). These variables are introduced in the *performance matrix,* in which each row describes an option (scenario) and each column describes the performance of the options against each criterion. It has been adapted from the methodology developed by the MCA Manual from the Department of Communities and Local Government in the UK[6].

Despite high uncertainties linked to the subjectivity of the method, MCA is considered an excellent pedagogical tool that allows identification, understanding, analysis, and discussion of the different aspects that influence the selection of strategies in an urban context. It is important that the criteria are evaluated by a multidisciplinary team, including environmental, ecological, social, urban, economic, and technical experts, in order to achieve the most integrated adaptation solution, while reducing uncertainty in the MCA results.

The methodology proceeds as follows, including the first two steps from the common approach:

1. **Involve relevant stakeholders** to discuss and decide on criteria and their weightings for the prioritisation and selection of adaptation options. Local and scientific knowledge can be integrated to provide a more comprehensive understanding of complex socio-ecological systems (Reed, 2008). This step is important to arrive at a set of options with a high level of social equity and acceptance. It is also relevant to involve them as early in the process as possible.
2. **Define objectives that indicate the direction of change desired**. In this case, the objectives are related to the increase of urban resilience against climate change impacts (e.g. floods, droughts, etc.), enabling planning and management across all

[6] Multi-criteria analysis: a manual. Department for Communities and Local Government, London, 2009

sectors (e.g. water, mobility, energy, etc.). Yet it can be fine-tuned to orient it towards a more social scope, e.g. adapt the city to minimize impacts of extreme weather events (common approach) (Reed, 2008).

3. **Identify the most suitable strategies to meet the objectives**. In the RESCCUE web-platform there is a large list of generic measures, available for analysts to select the best combination to create suitable strategies for each case study. It is also possible to introduce new measures developed by the interested parties. They must include information regarding costs, co-benefits scores and expected variation of recovery time (percentage). The proposed method invites again to define scenarios based on strategies including all measures and same strategies with subsets of measures (common approach).

4. **Define the evaluation criteria** for each scenario, which are the basis for the assessment of the given objective. As aforementioned, the proposed evaluation criteria are based on the RESCCUE framework:

    a. Investment costs. Available at the RESCCUE web-platform for the case studies. Although it is advised to adjust costs to the city of study

    b. City resilience, understood in this context as the recovery time of urban services after a shock. Although social-oriented strategies are not focused on services improvements, some of the measures that form some of these strategies act in an indirect manner on improving urban services. This fact, can be observed on the non-zero VRT matrix associated to these social-oriented strategies. Moreover, as this multi-criteria approach does not consider the use of Hazur® platform, a Services Impact Indicator (SII) [1] is proposed in order to take into account these potential benefits of social-oriented strategies on urban services. This indicator provides a percentage value that indicates how important is the effect of a social-oriented strategy on urban-services.

$$SII[\%] = \frac{\sum_{i,j}^{1} C_{i,j}}{\left[\sum_{i,j}^{1} C_{i,j}\right]_{max}} \cdot 100 \qquad \textbf{[1]}$$

    Where,

    $C_{i,j}$ is each of the VRT matrix components

    c. Social, economic and environmental co-benefits.

5. Complete the **Performance Matrix**:

    a. Scoring: the expected consequences of each scenario are assigned a numerical score on a strength of preference scale for each criterion. More preferred options score higher on the scale, and less preferred options score lower. In this case, co-benefits already come with a score from the platform, thus only scores should be given to investment costs and VRT (extracted from the web-platform). All attributes considered in the MCA would then fall between 0 and 10.

b. Weighting: numerical weights are assigned to define, for each criterion, the relative valuations of a shift between the top and bottom of the chosen scale.

Table 6 Example Box: Performance Matrix with strategies extracted from Barcelona's Climate plan

Strategies/Scenarios	Investment		SII [%]	Co-benefits			Score/Final Rank
	Cost	Score		Economic	Social	Environmental	
Taking care of everyone	650.000 €	3.0	0.2	6.5	5.6	6.0	4.69/4
No cuts	5.000.000 €	6.0	4.0	3.2	2.5	3.0	3.79/6
Preventing excessive heat	500.000 €	2.0	0.2	7.5	4.0	8.0	4.82/3
Recovering terrace roofs	800.000 €	4.0	1.0	5.0	3.0	7.0	4.45/5
Planning with a climate focus	1.000.000 €	5.0	14	9.0	10	9.5	8.83/1
Many more green areas	100.000 €	1.0	0.0	7.0	7.5	8.0	5.15/2
Proposed weights	25%		10%	20%	20%	25%	

MCA allows visibility of possible synergies with other goals such as disaster risk reduction, environmental management or welfare improvements. Focusing on options with multiple benefits can also facilitate the funding of the related actions by pooling resources and putting the emphasis on shared benefits that outweigh the investments (Lopez, 2018).

The actual measurement of indicators is based on quantitative analysis through scoring, ranking and weighting. Different environmental and social indicators may be developed side by side with economic costs and benefits. Explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives influence adaptation decisions.

Once prioritisation and selection of options are completed, they should be integrated in the Resilience Plan (WP6), providing the framework and planning for their implementation.

2.5 Conclusions and Remarks

The purpose of the prioritization method is to provide decision-makers a tool to facilitate the implementation schedule of the adaptation plan for any given city. However, the variety of categories of measures, and the different priorities of stakeholders make the mission of creating a standardized process rather cumbersome. Therefore, it is recommended in the first place to clearly address the major issues of the site, as it is done in the following section. From that point, and with the support of the other assessment tools provided by RESCCUE, the analyst will be able to select the most suitable ranking approach from the ones proposed.

The methods included are widely implemented, and do not require a high level of expertise. Nevertheless, they have some drawbacks, as mentioned in the description of each individual method.

Within RESCCUE project, the analyses that form both approaches will be allocated in different deliverables, according to the nature of each type of analysis. The approach 1, formed by the CEA and the CBA, will present the CEA in WP4 (D4.5) because the Hazur® assessment is provided in this WP4, and the CBA will be presented in WP3 (D3.5) because the damages

assessment for the different strategies scenarios is presented in this WP3. The sector models will be run by considering the effects of the adaptation measures, and the obtained results will be presented in WP2 (D2.5). Regarding social-oriented strategies, the approach 2 (multi-criteria analysis) has to be utilized, and it will be described in D5.3. Figure 3 and Figure 4 summarize the different analyses allocation described previously.

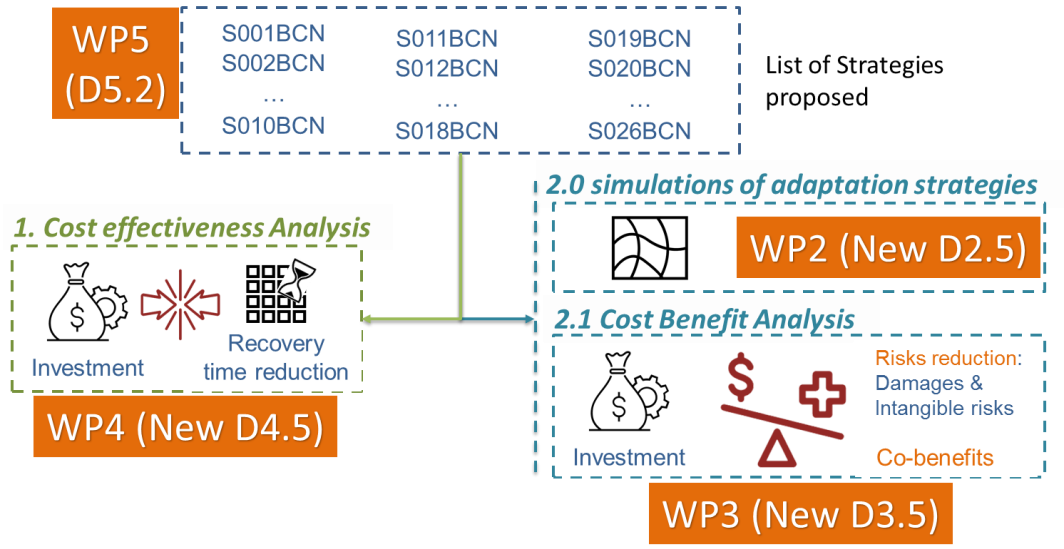


Figure 3 Allocation of the different analyses, corresponding to the approach 2, within the RESCCUE project deliverables.

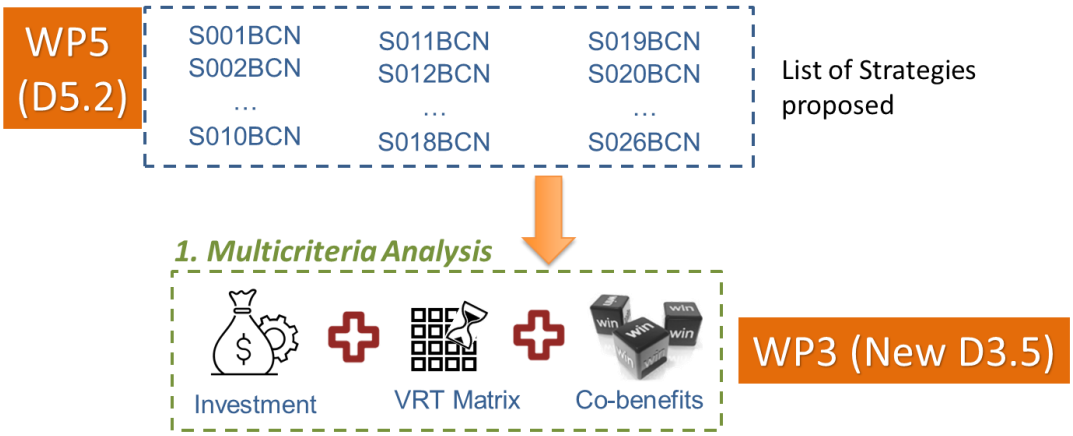


Figure 4 Allocation of the multi-criteria analysis corresponding to the approach 2, within the RESCCUE project deliverables.

3 Problem characterization and description of adaptation strategies

3.1 Introduction

In this section a list of the different adaptation strategies for Lisbon, Barcelona and Bristol is presented and validated, according to the main climate drivers that will threaten each city for the long-term future.

Each list is formed by strategies already identified by the city councils and contained in one or more plans, and also some new strategies identified in RESCCUE based on the expected climate impacts aggravation for the future.

As described in previous sections, the adaptation strategies and measures that form them will be prioritized according the proposed methodology.

These strategies are also collected and further described in the web-based platform developed in the framework of RESCCUE project: https://resccue2.herokuapp.com/resccue.

3.2 Barcelona strategies

The city of Barcelona is already committed with the challenge of climate change by planning and implementing mitigation and adaptation strategies in order to improve the quality of life and sustainability of the city. At COP21 in Paris, Barcelona presented the Barcelona's Commitment to the Climate (CBC), promoted by over a thousand businesses, citizen organisations and schools linked to the More Sustainable Barcelona network, signatories of the 2012-2022 Citizen Commitment to Sustainability and Barcelona City Council.

The Barcelona's Commitment to the Climate goals and targets for 2030 are as follows:

- As regards mitigation, to reduce its levels of CO_2 equivalent emissions by 40% per capita compared to those for 2005
- With regard to adaptation, to increase the urban green space by 1.6 km^2, in other words, 1 m^2 for each current resident

In order to achieve these goals the Barcelona City Council has elaborated the Barcelona Climate Plan, which includes existing measures and strategies along with new ones, while fulfilling the commitment it made when signing the Covenant of Mayors for Climate and Energy (2017).

The strategic lines in which the Climate Plan is based on are the following:

Mitigation, because we cannot allow a context of economic recovery to lull us into consuming in an unsustainable way again.

Adaptation and resilience, because we can already see the effects of climate change and we have to prepare ourselves.

Climate justice, because we need to put the most vulnerable people at the centre of climate policies.

Promoting citizen action, taking into account the Barcelona Climate Commitment while promoting co-creation projects.

The definition of mitigation and adaptation measures given in the Barcelona Climate Plan are as follows:

- **Mitigation**: all those measures geared towards reducing greenhouse gas emissions
- **Adaptation and resilience**: all those measures geared towards reducing vulnerability to climate change

The Climate Plan is an opportunity to join forces and make Barcelona a pioneering city that accepts responsibility for its contribution to climate change (reduces emissions), prepares itself to be less vulnerable to its effects (adapts) and becomes a fairer, more participatory city (promotes climate justice and citizen action).

As part of the policies for changing the model, to make the city a greener, fairer, more efficient and healthier place, various government measures and strategic plans have been drawn up over the last few years to achieve the climate goals. The Climate Plan recognises that these measures are already planned and therefore focuses on those that need to be developed further or on innovative measures that have not yet passed the planning stage.

The expected climatic values in Barcelona for the future, according to the RESCCUE project, are presented in WP1, and these results have been compared with the ones provided by Meteorological Service of Catalonia (SMC). The main reason of this comparison is that the Climate Plan is based on the projections obtained by the SMC. The RESCCUE project considered ten (the ones usable at daily scale) Earth System Model outputs available from the CMIP5 - Coupled Model Intercomparison Project Phase 5 (IPCC 5th report), whose outputs were statistically downscaled by employing the Ribalaygua *et al.* (2013) method. However, the SMC obtained the climate values from their climate change projections regionalized to the metropolitan area of Barcelona, using statistical downscaling applied afterwards to three different models. In general, for changes in the considered extreme events of temperature, the RESCCUE values are greater than the ones provided by the SMC, however both present trends that are alike. The description of the compared variables in Table 7 is as follows:

- **Heat Wave**: a succession of at least 3 days in which its maximum temperature lays above 98th quantile of the maximum temperatures of June-August reference period.

- **Warm day**: day whose maximum temperature is greater than that of 90th quantile of maximum temperatures of the reference period.
- **Tropical night**: night whose minimum temperature is higher than 20ºC.
- **Frost day**: day whose minimum temperature descends below 0ºC.
- **Extreme rainfall**: maximum rainfall registered in a day regarding a certain i-years return period

Table 7 Summary of the values concerning changes in extreme events of temperature regarding 2041-2100 and 2071-2100 periods. Values are indicated, if available, for RESCCUE and SMC with the median projected value and its uncertainty taking 10th and 90th quantile of the Ensemble distribution in the case of RESCCUE, and 5th and 95th for SMC

2041/2070	Historical value	*RCP 4.5*		*RCP 8.5*	
		RESCCUE	*SMC*	*RESCCUE*	*SMC*
Heat wave days (change in days)	5 days	--	--	+30 (+25/+50)	--
Warm days (change in %)	35 days	+110 (+70/+140)	+100 (+75/+125)	+110 (+70/+140)	+160 (+140/+170)
Tropical nights (change in %)	29 days	+110 (+80/+150)	+85 (+65/+115)	+150 (+120/+190)	+170 (+150/+180)
Frost days (change in %)	11 days	-30 (-20/-40)	-15 (-5/-30)	-35 (-30/-45)	-30 (-20/-40)
2071/2100	Historical value	*RCP 4.5*		*RCP 8.5*	
		RESCCUE	*SMC*	*RESCCUE*	*SMC*
Heat wave days (change in days)	5 days	--	--	+40 (+25/+80)	--
Warm days (change in %)	35 days	+145 (+100/+185)	+90 (+70/+150)	+200 (+170/+220)	+230 (+180/+250)
Tropical nights (change in %)	29 days	+150 (+130/+180)	+90 (+70/+150)	+310 (+240/+360)	+250 (+200/+270)
Frost days (change in %)	11 days	-40 (-30/-45)	-15 (-10/-25)	-45 (-35/-55)	-30 (-20/-50)

Regarding extreme rainfall, estimations from RESCCUE were made focusing on return periods, that is, how much would change its intensity in i-years return period event under a certain RCP (change from X mm to Y mm). However, SMC calculations were headed just in the opposite direction, taking a specific value of precipitation (50mm) and studying how much its frequency vary.

Despite the difficulty to work with extreme rainfall events due to their nature, the frequency of these events is expected to increase. Considering SMC results, frequency of a 50mm event is expected to increase a 15% for 2041-2070 period, while no significant change is expected by the end of the century. However, uncertainty is great, being equal to the median, and only leads to a low confidence projection of a slight positive trend during 2041-2070 period. With respect to 100-y return period extreme rainfall events, values obtained by RESCCUE range from +20% by the years 2041-2070 up to +40% by the end of the century, with uncertainty being ±15% and ±10% respectively, which make it a significant result.

Another important variable to be considered in RESCCUE project was the extremes in sea level rise which could threat the city of Barcelona as a coastal area. The projections for this variable were also taken into account in the Barcelona Climate Plan, however in this case those were

based on the studies conducted by Barcelona Regional (2017). In Table 8 the projections of both studies for this variable are presented for comparison purposes.

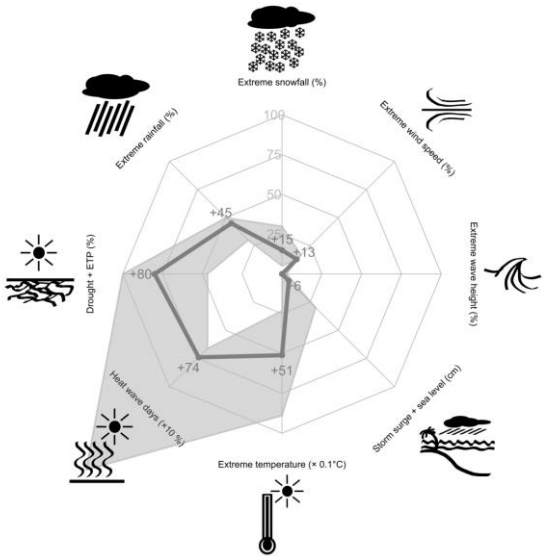
Table 8 Summary of the values concerning changes in future Sea Level for two horizons, year 2055 and 2100. Values are indicated, if available, for RESCCUE and Barcelona Regional study (2017).

2045/2055	*RCP 4.5*		*RCP 8.5*	
	RESCCUE	*Barcelona Regional (2017)*	*RESCCUE*	*Barcelona Regional (2017)*
Expected Mean Sea Level Rise (cm)	+10	+25	+30	+25
Expected Storm Surge (cm)	+88	+69	+88	+69
Total Extreme Sea Level Rise (cm)	+98	+84	+108	+84
2071/2100	*RCP 4.5*		*RCP 8.5*	
	RESCCUE	*Barcelona Regional (2017)*	*RESCCUE*	*Barcelona Regional (2017)*
Expected Mean Sea Level Rise (cm)	+20	+46	+30	+64
Expected Storm Surge (cm)	+88	+69	+88	+69
Total Extreme Sea Level Rise (cm)	+108	+115	+118	+133

Mean Sea Level values obtained by RESCCUE are generally lower than those gathered by the Barcelona Regional (BR) (2017) through their study, being alike by mid-century (+20cm FIC/+25cm BR) but almost the half by the end of it (+25cm RESCCUE/+55cm BR) for both RCPs. However, calculations for the storm surge show an increase of 88cm by RESCCUE and 69cm by the BR for all periods considered. As a result of this, the total most extreme sea level rise expected by both organizations is alike in all of the cases, with an average increase between RCPs of +105cm by RESCCUE and +85cm by BR by the year 2050, and of +115cm (RESCCUE) and +125cm (BR) by the end of the century. These results are satisfactory considering the different methodologies considered.

Generally, RESCCUE results behave in a way much alike Catalonian entities (both SMC and BR), which results are the basis of the Barcelona Climate Plan strategies, being RESCCUE outputs slightly greater in some cases, but within a common trend regarding the intensity of the change. Most important changes correspond, by far, to temperature, with a remarkable increase in all those variables related to it, especially heat wave days, depicting a future climate much warmer than today's. Changes in precipitation and sea level are, despite less significant and important, positive in all the cases (Figure 1).

As a summary of the RESCCUE results regarding future climate projections, an extremes compass rose for Barcelona is presented in Figure 5.



Most notable changes:

- Temperature related events. *Heat Waves Days* rising up to >1000%. Also droughts frequency and extreme max. T.
- Extreme rainfall more severe (greater accumulation in 12h time interval).

Figure 5. Extremes Compass Rose for Barcelona

Therefore, the alignment between projections which the Barcelona Climate Plan is based on and the ones obtained in the RESCCUE project has been proven. Thus, both are considering the same main climate threats for the city of Barcelona. In this sense, adaptation strategies of the Climate Plan and the ones proposed specifically in the RESCCUE project will be presented together in this deliverable D5.2 as a strategies list aiming to increase the resilience of the city of Barcelona.

However, the Climate Plan is definitely a people-oriented plan, being all the planned strategies mainly focused on social (also environmental) aspects. These strategies are expected to affect the city in the following ways:

- People's health and survival:
  - Heat has a direct effect on mortality, mainly on young children and elderly people
  - Climate change will be accompanied by new disease-bearing vectors, for example, tiger mosquitoes, which can transmit diseases produced by arboviruses, such as dengue, yellow fever, West Nile, chikungunya and Zika viruses
- People's quality of life and public safety:
  - More discomfort due to the heat
  - Need to improve the comfort of homes
  - Need for more friendly public spaces (shade, fountains, cool places)
  - Emergency situations caused by heat waves, flooding, drought or fires
- Guarantee of basic supplies:
  - Scarcity of water due to droughts
  - High energy demand due to extreme temperatures
- Cost of living:
  - Higher food and water prices
  - More poverty

- Environment:
  - Disappearance of species and landscapes
  - Appearance of pests and infestations and invasive species
  - Loss of beaches

RESCCUE project though, unlike Clime Plan, is more urban services-oriented and the strategies and measures identified pretend to enhance the services operation by reducing the time an infrastructure is down due to an specific shock, thereby reducing the potential cascading effect on the other urban utilities.

Following a complete list of 15 strategies is proposed for the city of Barcelona. The first 11 strategies are already proposed in the Barcelona Climate Plan [7] and the last 4 are the ones identified in the RESCCUE project according to the main notable changes expected for the future. For all of them a complete set of measures define each strategy, which will be prioritized later according to the methodology proposed in section 2. Moreover, the measures that form the Climate Plan strategies and have been highlighted in blue are those that their knowledge has been increased thanks to the RESCCUE results.

Table 9 Strategies list for Barcelona adopted from the Barcelona Climate Plan

I. TAKING CARE OF EVERYONE	***II. NO CUTS***
1. Provide tax incentives, grants and subsidies for housing energy improvements. 2. Promote the figure of the energy adviser. 3. Prevent electricity cut off, especially for the most vulnerable people. 4. Reduce the nuisance caused by bad smells by improving waste collection **5. Reduce the nuisance caused by bad smells by improving sewage systems in the event of hot weather.** 6. Strengthen the services for the most vulnerable people. 7. Design pilot projects for social superblocks 8. Adapt and improve the care services to help people face the impacts of climate change on health.	1. Promote and prioritise self-produce energy using renewable resources. 2. Guarantee water and energy supplies and uninterrupted service for critical facilities and infrastructures. 3. Study the impact that climate change could have on the price of basic supplies and food

[7] Just those measures and strategies from the Barcelona Climate Plan involving adaptation have been considered, those involving mitigation have been ignored as being out of the scope of this project.

9. **Renovate housing improving insulation to heat and flood, replacing obsolete electrical installations, etc**

III. PREVENTING EXCESSIVE HEAT

1. Identify existing and potential climate shelter spaces.
2. Deepen knowledge on how climate change affects health.
3. **Deepen knowledge on the urban climate (weather stations, etc.).**
4. Prioritise the cooling actions (green infrastructure, lakes, fountains, etc.) especially in those areas most vulnerable to heat.
5. Increase the reflectance index of city pavements and terraces

IV. RECOVERING TERRACE ROOFS

1. Draw up a by-law to promote productive roofs.
2. Draw up technical guidelines for public buildings that include the use of productive roofs, walls and facades.
3. Consolidate the green roof competition: one roof per district (annually)
4. Promote initiatives that publicise and tell people about productive roofs
5. Offer technical advice on productive roofs and walls
6. Promote rainwater collection and its reuse in buildings

V. PLANNING WITH A CLIMATE FOCUS

1. Adapt the necessary current urban planning regulations
2. **Draw up a design guide with sustainability and resilience criteria**
3. Draft a green and biodiversity charter
4. **Analyse how climate change specifically affects each district**
5. **Locate and characterise the areas at risk**
6. Influence higher-level planning instruments
7. **Characterise the various urban fabrics according to the risks that affect them**
8. Keep sufficient space in the soil and subsoil to allow for the necessary climate services
9. Rethink and adapt the criteria in project and works protocols and in

VI. MANY MORE GREEN AREAS

1. Incorporate CC criteria in the Special Plan for protecting the environment and landscape of the Serra de Collserola nature reserve
2. Create design criteria and, with public participation, plan the network of urban green corridors
3. Prioritise the actions planned in the PIVU in those districts and neighbourhoods with fewer green spaces and most exposed to heat
4. Consolidate the existing programmes to conserve wildlife vulnerable to CC
5. Consolidate the control programmes for arboviruses and other diseases
6. Find solutions to the problem of mosquito reproduction in scuppers and reservoir roofs
7. Produce a catalogue of tree species according to their capacity for resisting certain extreme climate conditions
8. Decide which zones need more thermoregulatory vegetation, those

the technical specifications for urban spaces

VII. NOT A SINGLE DROP WASTED. INCREASE WATER INFILTRATION

1. **Increase soil permeability by defining a sustainable urban drainage strategy for Barcelona**
2. **Use drainage paving**
3. Assess and continually monitor the quality of drinking water and groundwater to see if it is affected in periods of drought or heavy rain
4. Draw up a base map of the city's subsoil to find out the present degree of occupancy and impermeability and create reserve spaces for infiltration
5. **Build recharging pools at high points in the city and generate a flow retention and lamination effect, and install rainwater capture systems in Collserola so it can be reused. Evaluate their exploitation cost**
6. Envisage watering trees and increasing that whenever necessary for the desired evapotranspiration and cooling services

where it is not necessary and where xerophile vegetation is already sufficient

9. Improve our knowledge on the effects of climate change on natural systems
10. Create ephemeral or seasonal gardens

VIII. NOT A SINGLE DROP WASTED. GUARANTEE WATER SUPPLY

1. Foster water saving on a municipal level
2. **Incorporate up-to-date climate projections in future editions of the Drought Protocol**
3. Ensure compliance with the protocol for emptying water into naturalised ponds in the event of a drought, to preserve and protect amphibians and water plants
4. Have a Barcelona water supply plan in place
5. Promote the use of grey water in new housing developments and renovations or for industrial purposes, and study its inclusion in future versions of the Municipal Urban Environment Bylaw
6. **Study the energy impact of supplying water (the desalination plant, regenerated water plants, etc.)**
7. Study the feasibility of producing regenerated water at the Besòs WWTP to feed the Besòs aquifer, to maintain the river's ecological flows and feed the purification plant
8. Exploit the Besòs aquifer resource as potable water and build a purification plant
9. Utilise regenerated water from the River Llobregat for the industrial uses of the Zona Franca Consortium and for recharging the aquifer
10. Prevent saline intrusion by using regenerated water and surplus groundwater

IX. CONSERVING THE SEAFRONT

1. **Carry out further studies on the vulnerability of beaches to erosion and sea flooding**
2. Establish sediment conservation measures
3. Define the strategy for protecting and the specific use of each beach
4. Redefine existing coastal uses
5. Naturalise the Barcelona coast
6. Promote sustainable use of the sea
7. **Apply adaptation and resilience increasing measures that are suited to the Barcelona coast**
8. Increase marine biodiversity by installing artificial reefs
9. **Study the effects of climate change on the sea temperature**
10. **Reduce discharges into the receiving environment during periods of heavy rain and ensure that any water discharged into the natural environment is of sufficient quality**

X. CULTURAL ACTION FOR THE CLIMATE

1. Establish a specific call for grants to promote the citizen climate agenda, thus rewarding innovation and cooperation
2. Reinforce the support programmes in schools, shops and local organisations as spaces for climate awareness and action
3. Highlight the commitments, actions and good practices of the various stakeholders
4. Put a sustainability reference figure in place in each district
5. Strengthen the participation of the local community in defining urban development, green development and mobility plans for mitigating the effects of climate change
6. Conduct campaigns on climate change and its effects through the appropriate media, and widely publicise options and habits that help to combat it
7. Provide access to climate information through Smart Citizens and other applications

XI. LET'S GET ORGANISED

1. **Make public, through Open Data, relevant information on climate impacts and any monitoring action carried out (transparency)**
2. Take part in city networks to foster the exchange of good practices and collaborate with benchmark international institutions
3. Promote innovation and establish links with research centres to generate new knowledge on climate change
4. **Learn more about the impact of climate change on keeping critical city services and infrastructures going (health services, utility supplies, etc.) and how they depend on each other**
5. **Learn more about how climate change will affect Barcelona by taking part in the European RESCCUE project (2020)**
6. **Do a study on the possible economic effect of climate change on each sector**
7. **Create a resilience atlas that includes vulnerability maps which ensure the information is accessible to all the municipal players involved in urban planning, development and services**
8. **Revise municipal emergency plans in the light of the new information generated on climate change**

9. Improve the communication systems with critical city facilities and services during extreme climate episodes
10. Improve the public information provided in pollution episodes and warnings of new risks

Table 10 Strategies list for Barcelona identified in RESCCUE project

XII. FLOOD IMPACTS REDUCTION IN A CONTEXT OF CLIMATE CHANGE

1. Improvements of surface drainage system (New inlets)
2. Increase of sewer system capacity (I) (New pipes)
3. Increase of sewer system capacity (II) (New storage tanks for flooding protection)
4. SUDs (green roofs, infiltration trenches, detention basins for rural catchments)
5. Real Time Control Systems
6. Early Warning System
7. Ensure the stability of waste containers
8. Self-healing algorithm implemented in the electrical distribution grid

XIII. ENVIRONMENTAL IMPROVEMENT OF RECEIVING WATER BODIES

1. SUDS (green roofs, infiltration trenches, detention basins for rural catchments) (same respect to Strategy 1)
2. Increase of sewer system capacity (New storage tanks for environment protection)
3. Improvements of the capacity of sewer interceptor and WWTP
4. Real Time Control Systems
5. Early Warning System
6. End of pipe CSO treatment

XIV. GUARANTEE SECURITY OF SERVICES SUPPLY

1. Perform a Resilience Diagnosis of the city by using RESCCUE methodology and tools
2. Elaborate a Resilience Action Plan for the city according to RESCCUE methodology
3. Ensure the stability of waste containers
4. To locate a control center and a situation room

XV. NOT A SINGLE DROP WASTED. ALTERNATIVE WATER RESOURCES

1. Optimize desalinization plant production
2. Promote the use of grey water in new housing developments
3. Continue reducing leakage in distribution networks
4. Study the feasibility of producing regenerated water at the Besòs WWTP to feed the Besòs aquifer, to maintain the river's ecological flows and feed the purification plant
5. Exploit the Besòs aquifer resource as potable water and build a purification plant

6. Utilise regenerated water from the River Llobregat for the industrial uses of the Zona Franca Consortium and for recharging the aquifer
7. Promote rainwater collection and its reuse in buildings
8. Inter-basins connections
9. Increase the water cost for specific uses

Finally, and with the purpose of summarizing the identified strategies for Barcelona, Figure 6 is presented. The strategies identified in RESCCUE project are indicated together with their targeted hazards. Also the hazards which are targeted by the Barcelona Climate Plan are indicated in Figure 6.

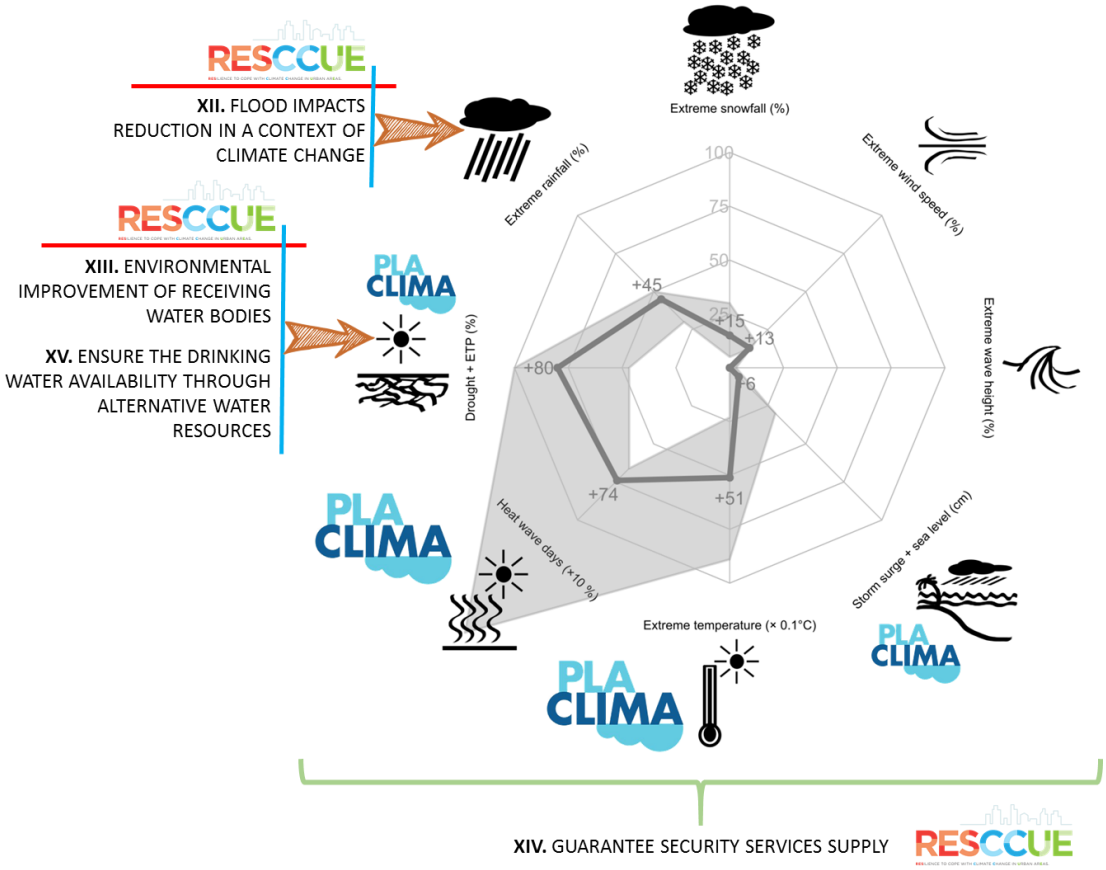


Figure 6. Coverage of strategies proposed for Barcelona per climate impacts

3.3 Lisbon strategies

Climate change is a global concern as the evidences are confirming the projections. The city of Lisbon has been considering the future climate impacts and is already compromised with climate change adaptation, integrating initiatives and measures to reduce the vulnerability of natural and human systems against the effects of climate change, whether effective or expected.

In 2017, Lisbon City Council approved the Municipal Climate Change Strategy (Estratégia Municipal de Adaptação às Alterações Climáticas, EMAAC), increasing knowledge and integrating climate change metropolitan adaptation measures through EMAAC results.

The EMAAC in Lisbon City Council is structured around the Climate Change National Adaptation Strategy core objectives:

- Improve the knowledge level on climate change as the basis for adaptation policies, based on continuous knowledge and monitoring;
- Adopt adaptation measures through specific objectives, outlined regarding the program lines in each strategic axis of EMAAC;
- Promote the integration of sectorial policies adaptation, promoted through actions and projects developed in urban planning, urban management and governance;
- Strengthen partnerships between entities and public and private bodies responsible for city management.

The environmental policies of Lisbon City Council have been reinforced by the participation in international organisations such as the Covenant of Mayors (2009) and Mayor's Adapt (2014).

In 2015, the group of Covenant of Mayors with the Mayor's Adapt initiative led to the new and integrated Covenant of Mayors for Climate and Energy. The Lisbon's Commitment to the Climate goals and targets for 2030 are as follows:

- As regards mitigation, to reduce its levels of CO2 equivalent emissions by 60% compared to those for 2002;
- Adopt and integrated approach to deal with climate change mitigation and adaptation.

In order to achieve these goals, the Lisbon City Council has elaborated the Sustainable Energies and Climate Action Plan (PAESC) and Lisbon Metropolitan Area is working on the Metropolitan Plan for Climate Change Adaptation (PMAAC). The strategic lines planned for the PMAAC are based on:

- Climate context;
- Actual and future vulnerabilities;
- Adaptation and mitigation strategies.

The plan has 3 strategic objectives and is being developed in 3 steps, considering agriculture and forests, biodiversity, economy, energy, water resources, human health, security of citizens and property, mobility and communications and coastal areas and sea (Table 11)

Table 11. PMAAC objectives

Objectives	Development steps
1. Promote the improvement of technical-scientific knowledge and its application to metropolitan territory	1. Adaptive base scenario
2. Institutional and territorial community empowering	2. Impacts and vulnerabilities
3. Adoption of a transversal culture of adaptation	3. Adaptation options

All the above plans focuses on the identification of options and adaptation actions that aim to promote the minimization of climate change effects. Based on identification and prioritization of current vulnerabilities and climate risks considering its projection until the end of the century, Lisbon compromises to propose an integrated set of adaptation options.

The projected climate values in Lisbon, according to the RESCCUE project, are presented in WP1, and these results have been compared with the ones provided by Portuguese Institute for Sea and Atmosphere (IPMA) (Paradinas *et al*, 2019). Considering all the Earth System Model outputs available from the CMIP5 - Coupled Model Intercomparison Project Phase 5 (IPCC 5th report), only ten of them are usable at daily scale. The data from the models were statistically downscaled using the FIC method (Ribalaygua *et al*. 2013) and applied to each of the climatic and extreme values projections.

IPMA results, which can be found at its specific climate Web, are obtained through a dynamical downscaling process using 5 different Regional Climate Models (RCM) from the EURO-CORDEX project, and then gathered through an Ensemble strategy in order to define uncertainty ranges. For some variables, common criteria between RESCCUE and IPMA when defining them are not achieved, so no comparison can be made. To solve this, some papers of previously made projects were gathered, or failing this, a comparison between defined-alike variables is done.

In general, for changes in the considered extreme events of temperature, RESCCUE values are slightly to moderately greater than those from IPMA depending on the variable considered, but trends observed are the same regarding the intensity of the change: towards a much warmer climate. The compared variables in Table 12 are similar to the ones described previously for Barcelona case study:

Table 12 Summary of the values concerning changes in extreme events regarding 2041-2070 and 2071-2100 period. Values are indicated, if available, for RESCCUE and IPMA with the median projected value and its uncertainty taking 10th and 90th quantile of the Ensemble distribution. *In discussion.

2041/2070	Historical value	*RCP 4.5*		*RCP 8.5*	
		RESCCUE	*IPMA*	*RESCCUE*	*IPMA*
Heat wave days (change in days)	5 days	--	--	+10* (+0/+20)	+5* (+2/+10)
Warm days (change in %)	37 days	+75 (+60/+100)	+60 (+50/+90)	+90 (+75/+110)	+75 (+60/+90)
Tropical nights (change in %)	12 days	+150 (+100/+225)	+125 (+50/+200)	+300 (+150/+375)	+150 (+100/+200)
Frost days (change in %)	0.5 days	0	+0	+0	+0

		(±0)	(±0)	(±0)	(±0)
2071/2100	Historical value	*RCP 4.5*		*RCP 8.5*	
		RESCCUE	*IPMA*	*RESCCUE*	*IPMA*
Heat wave days (change in days)	5 days	--	--	+15* (+0/+50)	+10* (+5/+20)
Warm days (change in %)	37 days	+100 (+50/+125)	+75 (+50/+100)	+175 (+150/+200)	+150 (+100/+175)
Tropical nights (change in %)	12 days	+200 (+150/+300)	+150 (+50/+200)	+500 (+450/+650)	+300 (+250/+400)
Frost days (change in %)	0.5 days	0 (±0)	0 (±0)	0 (±0)	0 (±0)

Regarding heat wave days, both results point to a warmer climate with more frequent heat episodes, with a total of +10/+15 days by the middle/end of the century according to RESCCUE results, and +5/+10 according to IPMA's.

Results shows a great increase in the number of warm days. By the middle of the century, RESCCUE points to an increase of up to +90% according to RCP 8.5, with little uncertainty (±15% approximately). IPMA shows an increase of up to +75% with the same range of dispersion.

Regarding tropical nights, results behave alike past ones, showing a large increase in expected future values with respect to the historical one. The trend is clear and results are coherent with climate projections, despite the low concordance between the two values.

RESCCUE's calculations for extreme rainfall were made focusing on return periods, as previously explained in the Barcelona case study. In this case we took as reference a 100-year return event of precipitation accumulated in 1h as a Lisbon City Council requirement. IPMA's calculated variables take as reference the opposite point of view, studying how much would the frequency of a certain accumulation of precipitation vary; in this case, days where rainfall is ≥ 50mm.

Sea level (**Table 13**) is another of the variables that was considered of enough interest to be studied in RESCCUE since it could affect Lisbon despite its inner location within the Tagus Estuary. This variable is not strictly a meteorological one due to the multiple factors that define it, so it was not taken into consideration in its study by the IPMA. So as to construct a comparison, data from Antunes *et al*. (2013) was used.

Table 13 Summary of the values concerning changes in future sea water level for both 2041-2070 and 2071-2100 periods. Values are indicated for RESCCUE and another study, with the median projected value and its uncertainty considering an Ensemble distribution.

Mean Sea Level Rise	RESCCUE RCP4.5	RESCCUE RCP8.5	Antunes et al. (2013) [AR4 High]
2041/2070 Expected Mean Sea Level Rise (cm)	+10 (-0/+25)	+15 (-0/+30)	+15 (+10/+30)
2071/2100 Expected Mean Sea Level Rise (cm)	+15 (-0/+40)	+20 (+5/+50)	+35 (+20/+60)

RESCCUE and Antunes' results are similar when compared by the mid of the century, with an increment of +15cm for both cases, although RESCCUE's uncertainty is a bit greater (even considering a no-change scenario). By the end of the century, Antunes' trend of raise is greater, resulting in a projected change of +35cm (±20cm) on the coasts of Lisbon; RESCCUE values however increase with a smaller slope, resulting in a rise of +20cm (±25cm

approximately). Despite the difference between results, the positive trend is common to both studies.

As a summary of the RESCCUE results regarding future climate projections, an extremes compass rose for Lisbon is presented in Figure 7. It indicates the maximum point change in climate extreme events along the century taking into account return periods between 2 and 100 years. The centre represents no changes and the edge corresponds to an increase of 100% for every variable except, for heat wave days (border is +1000%) and extreme temperature (border is +10°C). Thick lines represent the median scenario and the shaded area is the uncertainty region (5-95%). Snowfall and Wave Height are not considered as variables of study in Lisbon.

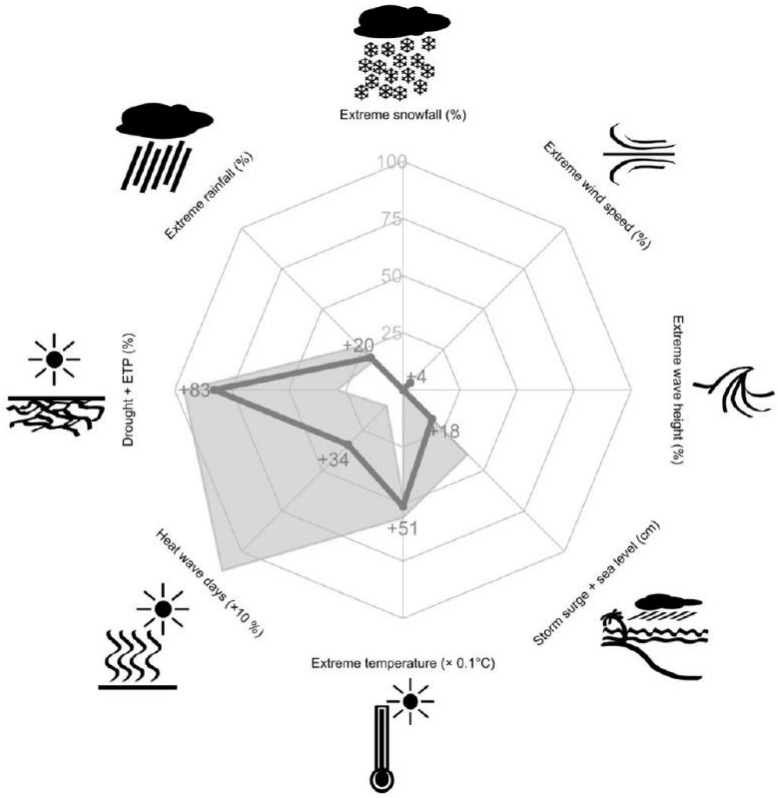


Figure 7. Extremes Compass Rose for Lisbon

Lisbon most notable changes:

- Temperature related events. Heat Waves Days rising up to >1000%; Droughts frequency rising up to 100% and Extreme temperature rising up to 7.5°C
- Extreme rainfall is more severe

Following a complete list of 20 strategies is proposed for the city of Lisbon. For all of them a complete set of measures define each strategy, which will be prioritized later according to the methodology proposed in section 2.

Table 14 List of strategies for Lisbon

I. Improve knowledge: city characteristics and vulnerabilities to flooding 1. Gather, manage and share high quality data to improve flooding risk assessment 2. Create and maintain flood risk asset registers (key assets for flooding risk and responsibility for their maintenance) 3. Identify higher risk areas by conducting studies involving flood modelling analysis 4. Inspection and cleaning of drains or sewer components	***II. Redesign urban landscape to enhance the water cycle functions: nature based solutions*** 2. Adding rain gardens before sewer inlet points 3. Filter strip 4. Provide flood storage areas via detention, retention or infiltration basins 5. Ponds and wetlands
III. Redesign urban landscape to enhance the water cycle functions: structural solutions 1. Provide flood storage via detention, retention or infiltration basins 2. Increase the network of waterways 3. Raise kerb or curb 4. Upgrading WWTP capacity in (wet weather lines) along with the collection capacity (including pumping stations)	***IV. Improve the resilience level at riverfront*** 1. Install flood proof fencing 2. Emergency response plans and procedures 3. Check valve and non-return valve 4. Build riverside flood defence walls
V. Adaptation of green infrastructure 2. Bioretention area 3. Implementation of rainwater harvesting systems (RWH) 4. Prioritize water allocation in a stress situation 5. Build promote urban forest and park	***VI. Increase ecosystem services: human well-being*** 1. Adding rain gardens before sewer inlet points 2. Implementation of RWH 3. Ponds and wetlands 4. Increase the network of waterways
VII. Promote urban rehabilitation as a tool to increase resilience: sewer systems 1. Rehabilitate sewer pipes 2. Inlets increase 3. On-source sediment traps 4. Construction of diversion tunnels	***VIII. Promote urban rehabilitation as a tool to increase resilience: facing climate change*** 1. Use non-potable water in compatible uses 2. Green roofs 3. Increase integration of renewable energy by Distributed Generation (DG) 4. Restriction on land-use areas vulnerable to flooding events

IX. *Promote citizenship and create networks to involve key stakeholders* 1. Develop community flood plans 2. Increase commitment to develop risk management strategies 3. Identify high risk areas by conducting studies involving flood modelling analysis 4. Public awareness, information, education and communication	**X. *Strengthening collaboration within AML, parishes and municipality departments*** 1. Increase commitment to city risk management 2. Effective communication of risk, considering relations among actors 3. Training, exercises and education to transfer scientific and operational knowledge to practitioners 4. Opportunities for citizens to participate in preparedness and response
XI. *Improving drainage of underground components of electrical infrastructure* 1. Install flood proof fencing 2. Learn from real-life flooding by recording and investigating events 3. Emergency response plans & procedures 4. Increase pumping capacity	**XII. *Engaging people in citizenship campaigns*** 1. Build promote urban forest and park 2. Use of alternative water source with adequate quality for supply 3. Increase of water storage capacity 4. Increase the reflectance index of city pavements and terraces
XIII. *Awareness about flooding risks* 1. Learn from real-life flooding by recording and investigating events 2. Effective communication of flooding risk, considering relations among actors 3. Training, exercises and education to transfer scientific and operational knowledge to practitioners	**XIV. *Update risk maps*** 1. Analyse coast effects of climate change 2. Level up or relocate substations near coastal and river areas 3. Build coast/ riverside flood defences 4. Flood forecasting and warning
XV. *Peak flow attenuation through the construction of three retention basins* 1. Identify high risk areas by conducting studies involving flood modelling analysis 2. Provide flood storage areas via detention, retention or infiltration basins 3. Create multi-purpose areas on flood storage areas	**XVI. *Construction of new components in drainage system*** 1. Increase number of inlets 2. Rehabilitate sewers 3. Construction of diversion tunnels 4. Construction of pollution retention basins

XVII. ***Lisbon drainage monitoring and early-warning system*** 1. Monitoring system to register and investigate flooding events 2. Implement permanent rain gauges, flow and water quality variables meters in a city wide system 3. Set up a real time control and warning system based on flooding forecasting	***XVIII. Architecture integration/solutions adaptations for urban electrical infrastructure to face overland flows or coastal water overtopping*** 1. Install flood proof fencing 2. Learn from real-life flooding by recording and investigating events 3. Emergency response plans 4. Build riverside flood defence walls
XIX. Building protections for urban electrical infrastructure, exposed to estuarine flood 1. Install flood proof fencing 2. Learn from real-life flooding by recording and investigating events 3. Emergency response plans and procedures 5. Build riverside flood defence walls	***XX. Use alternatives water sources taking into account severe droughts*** 1. Improved preparedness 2. Improve interoperability of the crisis management actors by development or implementation of practical standards 3. Prioritize water allocation in a stress situation Use of non-potable water in compatible

Please visit https://resccue2.herokuapp.com/ for more information about the strategies obtained within the RESCCUE project (username: user@resccue.com and password: User1234).

3.4 Bristol strategies

The **Bristol Resilience Strategy** considers stresses that are chronic conditions which weaken the fabric of a city on a daily or cyclical basis, such as climate change, combined with acute shocks that are sudden, sharp events, such as flooding. The strategy looks at addressing both the shocks and the stresses to enable the city to become more able to respond to adverse events, like extreme weather conditions, to continue to deliver basic functions.

The 50 year plan (to 2066, following publication) takes account of global climate stresses and changing weather patterns amongst other resilience issues. By analysing the resilience diagnosis of the past and its current status, an approach to future challenges has been devised. Broad categories like Infrastructure and environment, economy and society, leadership, strategy, health and wellbeing have been distinguished. These are further broken down in to related sections. Various aspects were covered with a range of stakeholders. More specific sections such as renewable energy and waste management have been determined, these example themes having a link to the management of climatic impacts. Areas related to the RESCCUE works include enhancing natural and man-made assets and ensuring continuity of critical services. As Bristol was the first UK city to hold the title of European Green Capital in 2015 there is a focus on green infrastructure and practices. Ambitious public commitments have been made to be zero carbon by 2050. However, we know that more audacious, bolder steps are needed to transform the built environment and people's behaviours. We also know that increasing uncertainty, particularly in relation to a changing climate, means that we need to adapt to future uncertainty and risk. Managing stresses such as transport congestion and ageing infrastructure is an important part of this challenge. Radical solutions, coupled with new forms of financing, must be secured to transform Bristol into an attractive and prosperous post-carbon city. Reducing Bristol's carbon footprint and waste streams are key aims of the council's, as are the following:

Liveable

The city centre and neighbourhoods are great places for people of all ages to live, work, learn and play.

Goals, by 2066 Bristolians will:

- Benefit, across the whole city, from the multi-functional value of green infrastructure and the natural environment
- Live in an all age-friendly city, with all ages able to access all necessary services within a 20 minute journey by active travel or a sustainable mode of transport
- Achieve clean air for Bristol

Addressing the resilience paradoxes: Green infrastructure and the natural environment can provide multiple benefits such as active travel, improved air quality, improved health and wellbeing, and reduced impacts of flooding, climate change, and environmental degradation, and reduced transport costs.

Sustainable

The city and region prosper within environmental limits through adopting new behaviours and technology.

Goals, by 2066 Bristolians will:

- Develop a zero waste city
- Live in a carbon neutral city
- Operate environmentally responsible and fair-trade supply chains

Addressing the resilience paradoxes: To live within our environmental limits we will aim to use resources (products, components and materials) to their highest utility in the economy. This builds resilience by reducing the impact of resource scarcity (e.g. energy, food, water, materials), future-proofing our infrastructure and our economy, and protecting our natural environment.

Green and Black

Inclusiveness and environmental awareness are key concerns for Bristol now and in the future. The Green and Black initiative aims to kick start a long term series of activities and relationships with Black and Minority Ethnic (BAME) communities around the legacy of the European Green Capital year.

This action will focus on developing young BAME ambassadors to raise environmental awareness in their communities and more broadly around the city. It is intended that the programme will engage the 'future city' academics at the universities and act as a catalyst for one or more corollary projects in both the Impact and Research agendas.

One larger scale project is hoped to emerge that the partners can take to an external funder (e.g. Esmée Fairbairn) for support.

Delivery

- Potential partners: Bristol Green Capital Partnership, Ujima, University of Bristol, Bristol City Council, Social Intelligence Institute
- Timescale: Medium-term

Resilience value: The empowerment of young BAME citizens to share environmental awareness with communities and the city improves inclusiveness and understanding of environmental issues.

Community-based adaptation

Communities that are self-organised in day to day life are inherently better prepared to respond to, and recover from, unexpected events in their neighbourhoods.

Community based adaptation (CBA) has been pioneered in developing countries to build capacity in vulnerable and marginalised communities to become more resilient to climate change impacts. An important lesson from CBA practices is that a multilevel, cross-sectoral approach involving a range of different stakeholders – including the residents themselves - is necessary to develop adaptive capacity and build long term resilience.

This action builds on the principles of CBA and experience from a number of existing projects and initiatives in Bristol, the south west and other cities around the world. It aims to develop a more integrated and inclusive approach to working with communities to empower them with the knowledge, confidence and resources to take action when affected by local shocks.

Delivery

- Potential partners: Bristol City Council, Cities of Service team, Local Resilience Forum, Groundwork (funded by Big Lottery Fund), Bristol Resilience Network, Community Development teams, UL Cabinet Office, Voscur
- Timescale: Short-term

Resilience value: Providing communities with the resources and capacity take action to deal with shocks means neighbourhoods will be better able to respond and recover from events.

Legible City

Bristol Legible City (BLC) is an innovative project started 20 years ago as a unique concept to improve people's understanding and experience of the city through the use of identity, information and transportation projects.

The project has recently agreed funding for the next initiative which is to develop innovative city mapping and information resources to support change to more sustainable forms of transport and encourage active travel choices. The initiative will deliver a suite of digital, printed and street-based information products to encourage residents and visitors to explore the city on foot, bike and using the public transport system. BLC's user-centred approach to wayfinding and transport information has been developed to support better public health and reduce greenhouse gas production.

The initiative will deliver an enhanced pedestrian wayfinding system across the city and develop new user-friendly information for the cycle network, the MetroBus project and the wider public transport system.

Delivery

- Potential partners: BCC, Legible City, MetroBus
- Timescale: Short – medium-term

Resilience value: Improving communication of sustainable and active travel options will increase citizen take up and help improve wellbeing and reduce congestion.

Bristol Transport Plan

This action will promote the development of a 20 year plan to create better places and help people move around by enabling a large scale shift to sustainable transport in Bristol. We currently have plans to deliver new transport infrastructure within the current funding and planning cycles, this strategy will enable us to look further ahead and to test more radical interventions to reduce congestion, carbon emissions and ensure infrastructure is resilient to climate change.

To support the development of this strategy, we will explore working with MIT

(Massachusetts Institute of Technology) Smart to quantify the impact of different transport options. We will use 50 year scenarios to support strategy development, and will ensure other transport strategy refresh projects are integrated with this longer-term view.

Delivery

- Potential city partners: Bristol City Council (Transport); Network Rail, West of England Authorities, Sustrans; First Group; Bristol Ageing Better; Child Friendly City; University of the West of England
- Potential 100RC platform partners: MIT Smart
- Timescale: Medium-term

Resilience value: Resilience value: Lowering the number of car journeys and increasing active travel will help to protect the natural environment, through improved air quality and reduced carbon emissions, improve health and wellbeing, and reduce transport congestion costs.

Clean air city

Bristol is part of an EU funded consortium of universities and research institutions to actively engage European citizens in measuring their personal impact on air quality and CO2 emissions in their cities. The project will use innovative tools like specially made apps and games for smart phones to generate citizen-led policies to improve air-related health in our cities.

Thousands of people across Europe will be invited to share their views on how to reduce air pollution and improve related public health in six pilot cities. Residents will use a game on their smartphones, tablets and laptops to suggest how their home cities should develop in the future. The result will be directly translated in improved city policies.

In Bristol we will focus on raising awareness about poor air quality and work with citizens to identify simple actions that can improve air quality in their local streets.

Delivery

- Potential partners: University of West of England, Bristol City Council
- Timescale: Medium-term

Resilience value: Engagement with citizens over air quality issues and actions that can improve their city increases both social connectivity and air quality benefits.

Climate change adaptation plan

As a signatory of the Compact of Mayors, Bristol has a long-established approach to climate change mitigation. This action will build on this success and develop an approach to adaptation to climate change.

A plan will be developed to future-proof the city by identifying the major climate hazards and their potential impact, a framework for adaptation, and identification of strategies to build climate resilience. Consideration of the issues will be required at a city scale with actions targeted at a local scale with their benefits well communicated.

Delivery

- Potential partners: Bristol City Council

- Timescales: Short-term

Resilience value: A climate change adaptation plan will identify risks and strategies to mitigate these challenges, building resilience across the city.

Establishing a resilient city financing structure

Bristol will explore options for establishing a resilient city financing structure by aggregating a suite of small and large scale place-based projects focusing on improving local resilience (e.g. flood defences, green infrastructure, community facilities and new housing). The structure would seek to blend public and private money and take a long term view (at least 25 years) to achieve a social as well as a financial return on investment.

Delivery

- Potential partners: Bristol City Council, Bristol Energy and Waste Companies, Bristol & Bath Regional Capital Community interest Company, University of Bristol, University of West of England
- Timescale: Medium-term

Resilience value: We know that we need investment that is able to recognise longterm resilience value, rather than just short-term financial returns. We aim to deliver jobs and skills for local people, whilst empowering citizens to support projects they are passionate about, and providing key infrastructure assets for Bristol.

Manage our future flood risk

Tidal flooding from the River Avon has the potential to cause severe damage to the city centre. Bristol's Central Area Flood Risk Assessment (CAFRA) predicts that the current trend of rising sea levels will accelerate due to the impact of climate change, causing the likelihood of tidal flooding in central Bristol.

A strategy is being developed to recommend an adaptive programme, identify when flood risk management interventions are needed and examine how they will be funded.

Delivery

- Potential partners: Bristol City Council, Environment Agency, Local Enterprise Partnership
- Timescale: Medium-term

Resilience value: Bristol needs to be bolder in how in responds to the changing climate. This action aims to future-proof Bristol's infrastructure and wider assets, whilst also promoting long-term planning.

Wild rainwater streets

Greening local neighbourhoods helps to make our city more liveable, whilst also improving local biodiversity, enhancing sustainable drainage, and reducing the urban heat island effect and improve the city's resilience to climate change. Bristol will build on existing initiatives, including Avon Wildlife's Trust's My Wild Street, Wessex Water's Rainwater City, and Embleton Road SuDs, to develop an approach that communities across the city can engage in.

Delivery

- Potential partners: Bristol Green Capital Partnership, Bristol City Council, Avon Wildlife Trust, Wessex Water, Sustrans
- Timescale: Medium-term

Resilience value: Greening neighbourhoods improves citizen wellbeing while improving the cities resilience to climatic change.

Protecting and valuing green space

We will develop a high level assessment of the financial value of green spaces across the city to assist with future investment decisions. A valuation analysis of the natural capital in Bristol's parks will be conducted, which includes certified values of each ecosystem service. There is a lack of sustainable funding for green infrastructure. This assessment will provide an evidence base to support increased uptake and delivery of green infrastructure projects, both improvements to existing green space and delivery of new projects.

Delivery:

- Potential partners: Bristol City Council, Avon Wildlife Trust, Local Nature Partnership, Natural Capital Trust, Bristol & Bath Regional Capital CiC, Arcadis
- Timescale: Medium-term

Resilience value: Multiple benefits of green infrastructure uptake may be experienced including improved air quality, improved human wellbeing, and reduced impacts of flooding, climate change, and environmental degradation.

Natural Capital Trust

We will support the development of the Natural Capital Trust (NCT) as an innovative mechanism to deliver enhancement in the quality of the natural environment across the West of England region. The NCT will act as a conduit of funds from developers, and from potential beneficiaries of Payments for Ecosystem Services schemes, to support a range of projects which ensure provision of services by ecosystems, enhancing (amongst other things) resilience to the effects of climate change and of the region's infrastructure.

Delivery:

- Potential partners: Bristol City Council (and other local authorities in the region); West of England Nature Partnership; Health and Wellbeing Board; Local Enterprise Partnership; utility providers; developers; English Nature; Environment Agency; Highways Agency
- Timescale: Medium-term

Resilience Value: Supporting and funding projects which enhance ecosystem services can provide a range of resilience benefits from improved well-being to reduced impact from extreme climate events.

Urban Integrated Diagnostics

The Urban Integrated Diagnostics project promotes research and innovation initiatives that help to improve the city's health, well-being and prosperity as they face up to challenges of modern urban living.

The Bristol 'pilot' project will bring citizens together with researchers, local authorities and partners from business and the voluntary and community sector aimed at investigating the very real challenges facing the city across four areas: mobility and accessibility, health and happiness, equality and inclusion, and tackling dependency on fossil fuels. Bristol will learn from other pilot cities of York, Leeds, Newcastle & Gateshead, and Birmingham.

Delivery

• Potential partners: Bristol City Council, South Gloucestershire Council, University of Bristol, University of the West of England

• Timescale: Short-term

Resilience Value: This project will help Bristol to learn and adapt, improving our knowledge, helping to tackle stresses such as inequality and transport congestion.

Resilience Impact Assessment

Bristol City Council currently requires major initiatives and investments to be subject to an Environmental Impact Assessment (EIA) and an Equalities Impact Assessment (EQIA). The use of a resilience lens to assess the impact of initiatives and projects would provide an integrated and systemic view of risks and impacts associated with city interventions. Some 100RC cities such as have introduced the use of the resilience lens to assess projects. New Orleans, for example, has established a Resilience Design Review Committee for regular project review.

The release of this strategy provides a timely opportunity to consider how resilience is embedded into design and implementation of city and regional projects. A group of officers will be convened in the City Council to develop proposals for integrating resilience thinking into internal assessment processes.

Delivery

• Potential partners: Bristol City Council, 100RC Cities

• Timeline: Short-term

Resilience Value: Providing a means of assessing project resilience will enable that resilience to be a key consideration which influences design for projects.

Resilience and West of England devolution deal

Bath, Bristol and South Gloucestershire councils have proposed £1bn West of England devolution deal which is now up for public consultation. The deal would devolve, from the government, agreed funding and powers to the region, including decisions regarding transport, investment, funding, skills training, business support, housing and strategic planning.

A workshop will be held to explore how devolution of funding and powers could improve city resilience through integrated into the new governance structures.

Delivery

• Potential city partners: Bristol City Council, Bath and North East Somerset Council, South Gloucestershire Council, West of England Civil Society Partnership

• Timescale: Medium-term

Resilience Value: Devolution will provide city regions in the UK with funding and powers across skills, infrastructure, and strategic planning. This action will help to embed resilience into those areas.

British Standard on city resilience

The British Standards Institute is working to develop a good practice guidance standard in relation to city resilience.

Bristol, amongst other 100RC cities, will host a workshop to inform the development of the standard, peer reviewing the intended approach. This is to reflect the status and work that is continuing in Bristol to make it more resilient.

The standard will act as guidance for the city leaders and as a management framework for executives with responsibility for different resilience themes within cities.

Delivery

• Potential partners: Cabinet Office, Glasgow, Manchester, London, 100RC

• Timescale: Short-term

Resilience Value: Supporting the development of a city resilience standard will promote the concept of resilience to city leaders and organisations and provide guidance to others, as well as assisting Bristol with its process of continual learning.

Climate Strategy and Energy Framework

Bristol City Council has created the 'Framework for Climate and Energy Security' as part of being European Green Capital in 2015. This is the start of an ambitious process which seeks to create an integrated, adaptable and inclusive, sustainable city. This low carbon plan will be vital to reach the new target for Bristol to be Carbon Neutral by 2050. This is to be reviewed and refreshed every three years to provide a continuous process of improvement.

Delivery

• Potential partners: Bristol City Council

• Timescale: Medium-long term

Resilience Value: Providing continuity of energy supply in an uncertain future is an important part of a resilient Bristol.

Adaptation & resilience framework for the Bristol Avon catchment

This is a multi-agency collaborative initiative to identify opportunities and risks for organisations by climate change disruption and economic austerity through greater integration of actions across sectors and political boundaries working at a catchment scale. This innovative initiative is in the process of engaging with other key strategic planning organisations and infrastructure providers to understand the interdependent risks and opportunities and deliver cross-sectorial adaptation actions in spatial planning at a catchment scale. It will address relevant Global Sustainable

Development Goals at a local scale and highlight where the enhancement of our regional natural capital could be made in multiple distributed locations, to deliver multi-beneficial outcomes from collaborative investments.

By integrating the framework into existing work streams, operational and investment plans, development decisions can be made based on wider identified risks, with wider costed solutions and routes to delivery that enhance the value of existing and future investments in the region.

The ultimate aim is to create an attractive sustainable place for future generations, with a strong regional economy and enduring infrastructure supported by sustainable agriculture and resilient natural capital.

Delivery

• Potential partners: Wessex Water, Environment Agency, Natural England, Highways England, Bristol City Council, South Gloucestershire Council, Bath and North East Somerset Council, Wiltshire County Council, West of England Nature Partnership, Wiltshire Wildlife Trust, West of England Local Enterprise Partnership, Wiltshire and Swindon Local Enterprise Partnership, Bristol Water, Bristol Avon Catchment Partnership.

• Timescales: Medium-term to Long term

Resilience Value: This approach is bringing together a wide range of stakeholders with diverse interests to plan in an integrated way for the long-term resilience of our region's natural resources. This offers a resilience dividend in terms of increasing resilience to climate change risks as well as improving biodiversity, recreation, food production and reducing costs associated with treating polluted water course.

Clean Air for Bristol was set up to address the city's failings in meeting the legal requirements for air pollution rates which developed Bristol's Clean Air Plan. Monitoring takes place to retrieve pollutant data, such as for oxides of Nitrogen and particulate matter. Bristol City Council declared an Air Quality Management Area in 2001 for Nitrogen Dioxide (NO2) and Particulates (PM10). Approximately 100,000 people live in this area and there are 35 schools. Measures have been put in place to combat these ill effects. Clean Air Zones are a possibility by charging the worst polluting vehicles and improving air quality. Bristol has been successful at improving walking, cycling and bus usage in recent years. Other Initiatives include working with bus operators to clean up the bus fleet. BCC also ensures its own fleet of vehicles is clean, by using electric pool cars, some electric vans, some other ultra-low emission vehicles (ULEVs) and providing training for drivers. BCC are working with providers to increase the number of

EV charge points and the Metrobus programme will enable residents to leave the car at home and use a clean, high quality rapid transit service.

Bristol has also planted 50,000 trees. It is possible these will have a small positive impact on air quality but it is likely this will be too small to measure.

Other transport interventions that will improve air quality are listed below.

- The MetroWest project will improve existing rail provision across the sub-region, including the opening of new stations and increased frequency on local lines.
- Large-scale investment in walking and cycling through the Cycle Ambition Fund which is creating new routes and improving existing infrastructure.
- MetroBus, a rapid public transport system that will provide an express service to key destinations in the area using a combination of segregated busways and lanes, will use low emission vehicles.
- Ensuring the council fleet vehicles are modernised to reduce pollution by replacing out of date diesel vehicles. This being supported by a £7 million project to provide over 200 more public and business charging points across the city region. It will also enable people to buy new electric cars with confidence that they can charge them.
- Increasing the proportion of electric pool cars available for council employees to use on city trips.
- Changes to Taxi Licencing Policy to improve taxi fleet emissions

The whole of Bristol is a smoke control area (SCA) which aims to ensure emissions from solid fuel are controlled to some extent. This means that people can either: burn an authorised smokeless fuel in any appliance or are permitted to burn a wider range of fuels if using an exempt Defra exempt alliance. A Defra exempt appliance is a burner that is designed to burn fuel efficiently to reduce emissions (however these still emit high levels of pollution – see above). Breach of these rules in Bristol can result in a fine of up to £1,000. It is an offence to burn wood on an open fire in Bristol under the smoke control regulations.

Particular climate based aspects predicted to affect Bristol in the future consist of sea level rise, changes in rainfall intensity and heightened river flows.

The below tables outline how these predicted projections are expected to increase over time. Through the RESCCUE project in Work Package One a comparative review of RESCCUE climate projections versus UK Climate Projections 2009 (UKCP09) was made. This is summarised as follows.

Table 15 Summary of the values concerning changes in extreme events regarding 2071-2100 period. Values are indicated, if available, for FIC and Met Office with the median projected value and its uncertainty taking 10th and 90th quantile of the Ensemble distribution. Met Office values correspond to *Yeovilton village.

2071/2100	Historical value	RCP 4.5		Most severe (RCP 8.5/A1FI)	
		RESCCUE	*UKCP09*	*RESCCUE*	*UKCP09*
Heat Wave Days (change in days)	FIC: 4 days* UKCP09: 0 days*	--	--	+15 (+2/+44) *	+10 (+0/+34) *
Warm days (change in %)	FIC: 35 days* UKCP09: 8 days*	+130 (+70/+180)**	--	+210 (+130/+240) *	+700 (+300/+1100) *
Tropical nights (change %)	1 days	+500 (+0/+1000)	--	+1500 (+1000/+3500)	--
Frost days (change in %)	40 days	-60 (-70/-40)	--	-85 (-100/-70)	-70 (-90/-35)

Table 16 Summary of the values concerning changes in extreme rainfall events for both 2041-2070 and 2071-2100 periods. Values are indicated, if available, for FIC and Met Office, with the median projected value and its uncertainty taking 10th and 90th quantile of the Ensemble distribution. *Yeovilton village.

	Historical value	2041-2070		2071-2100	
		RESCCUE	*UKCP09*	*RESCCUE*	*UKCP09*
Extreme 1-y rainfall 24h (change in %)	33 mm*	--	--	--	+25 (+5/+55) *
Extreme 2-y rainfall 12h (change in %)	27 mm	+20 (+10/+35)	--	+40 (+20/+60)	--
Extreme 100-y rainfall freq. (change in y.)	100 years	--	-10 (-20/+15)	--	-15 (-25/+20)
Extreme 100-y rainfall 12h (change in %)	35 mm	+30 (+15/+40)	--	+40 (+30/+60)	--

Table 17 Summary of the values concerning changes in future Sea Level for both 2041-2070 and 2071-2100 periods. Values are indicated for FIC and Met Office, with the median projected value and its uncertainty taking 10th and 90th quantile of the Ensemble distribution.

Mean Sea Level Rise	***RCP4.5***	**RCP8.5**	**Mean Sea Level Rise**	***RCP4.5***
	RESCCUE	*UKCP18*	*RESCCUE*	*UKCP18*
2041/2070 (change in cm)	+10 (-5/+25)	+30 (+20/+40)	**2041/2070 (change in cm)**	+10 (-5/+25)
2071/2100 (change in cm)	+15 (-5/+50)	+50 (+35/+80)	**2071/2100 (change in cm)**	+15 (-5/+50)

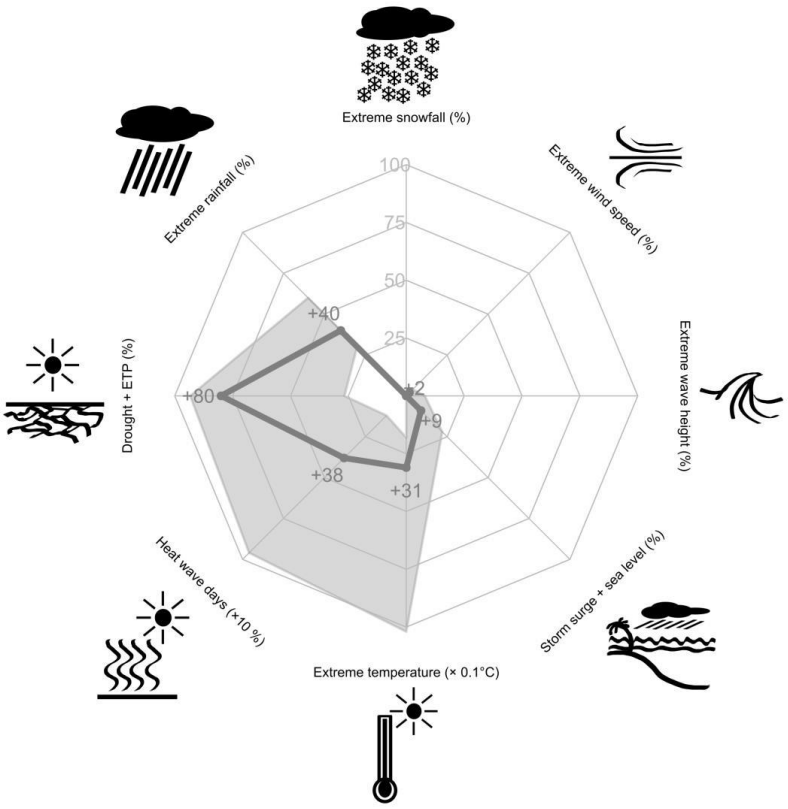


Figure 8. Extremes Compass Rose for Bristol: Maximum point change in climate extreme events along the century taking into account return periods between 2 and 100 years. The centre represents no changes and the edge corresponds to an increase of 100% for every variable except for heat wave days (border is +1000%) and extreme temperature (border is +10°C). Thick lines represent the median scenario and the shaded area is the uncertainty region (5-95%).

The above climate predictions have helped develop the following RESCCUE adaptation strategies in conjunction with the Bristol Local Flood Risk Management Strategy.

Following a complete list of 18 strategies is proposed for the city of Bristol. For all of them a complete set of measures define each strategy, which will be prioritized later according to the methodology proposed in section 2.

Table 18 List of strategies for Lisbon

I. Green and Black	***II. Community-based adaptation***
1. Long term series of activities and relationships with Black and Minority Ethnic (BAME) communities 2. Developing young BAME ambassadors to raise environmental awareness in their communities and more broadly around the city.	1. A multilevel, cross-sectoral approach involving a range of different stakeholders – including the residents themselves - is necessary to develop adaptive capacity and build long term resilience. 2. Following the Community Based Approach (CBA) to develop a more integrated and inclusive way to working with communities and empower them

	with the knowledge, confidence and resources to take action when affected by local shocks.
III. ***Legible City*** 1. Develop innovative city mapping and information resources to support change to more sustainable forms of transport and encourage active travel choices 2. Deliver a suite of digital, printed and street-based information products to encourage residents and visitors to explore the city on foot, bike and using the public transport system 3. Enhanced pedestrian wayfinding system across the city and develop new user-friendly information for the cycle network, the MetroBus project and the wider public transport system 4. Improving communication of sustainable and active travel options to increase citizen take up and help improve wellbeing and reduce congestion.	**IV.** ***Bristol Transport Plan*** 1. Deliver new transport infrastructure to reduce congestion, carbon emissions and ensure infrastructure is resilient to climate change 2. Work with Massachusetts Institute of Technology Smart to quantify the impact of different transport options 3. Use 50 year scenarios to support strategy development, and ensure other transport strategy projects are integrated with this longer-term view
V. ***Clean air city*** 1. Use innovative tools like specially made apps and games for smart phones to generate citizen-led policies to improve air-related health in our cities 2. Thousands of people across Europe will be invited to share their views on how to reduce air pollution and improve related public health in six pilot cities. Residents will use a game on their smartphones, tablets and laptops to suggest how their home cities should develop in the future. The result will be directly translated in improved city policies 3. In Bristol the focus will be on raising awareness about poor air quality and work with citizens to identify simple	***VI.*** ***Climate change adaptation plan*** 1. A framework for adaptation, and identification of strategies to build climate resilience 2. Consideration of the issues will be required at a city scale with actions targeted at a local scale with their benefits well communicated

actions that can improve air quality in their local streets	
VII. Establishing a resilient city financing structure 1. Blend public and private money and take a long term view (at least 25 years) to achieve a social as well as a financial return on investment on flood defences, green infrastructure, community facilities and new housing 2. Provide key infrastructure assets and jobs in order to facilitate this	***VIII. Manage our future flood risk*** 1. Recommend an adaptive programme to identify when flood risk management interventions are needed and examine how they will be funded to ensure continued and sustainable growth in the city's economic hub
IX. *Wild rainwater streets* 1. Build on existing initiatives, including Avon Wildlife's Trust's My Wild Street, Wessex Water's Rainwater City, and Embleton Road SuDs, to develop an approach that communities across the city can engage in.	***X. Protecting and valuing green space*** 1. Valuation analysis of the natural capital in Bristol's parks will be conducted, which includes certified values of each ecosystem service. 2. Provide an evidence base to support increased uptake and delivery of green infrastructure projects, both improvements to existing green space and delivery of new projects
XI. Natural Capital Trust (NCT) 1. Provide support to the wider NCT project 2. Identify and implement funding from developers, and from potential beneficiaries of Payments for Ecosystem Services schemes, to support a range of projects which ensure provision of services by ecosystems, enhancing (amongst other things) resilience to the effects of climate change and of the region's infrastructure	***XII. Urban Integrated Diagnostics*** 1. Bring citizens together with researchers, local authorities and partners from business and the voluntary and community sector aimed at investigating the very real challenges facing the city across four areas: mobility and accessibility, health and happiness, equality and inclusion, and tackling dependency on fossil fuels 2. Learn from other pilot cities of York, Leeds, Newcastle & Gateshead, and Birmingham

	3. Learn and adapt, improving our knowledge, helping to tackle stresses such as inequality and transport congestion
XIII. Resilience Impact Assessment 1. Provide an integrated and systemic view of risks and impacts associated with city interventions 2. Consider how resilience is embedded into design and implementation of city and regional projects 3. A group of officers will be convened in the BCC to develop proposals for integrating resilience thinking into internal assessment processes	***XIV. Resilience and West of England (WoE) devolution deal*** 1. Workshop held to explore how devolution of funding and powers could improve city resilience through integration into the new governance structures 2. Embed resilience into those areas of devolved powers of skills, infrastructure, and strategic planning
XV. British Standard on city resilience 1. Bristol, amongst other 100RC cities, will host a workshop to inform the development of the standard, peer reviewing the intended approach 2. The standard will act as guidance for the city leaders and as a management framework for executives with responsibility for different resilience themes within cities.	***XVI. Climate Strategy and Energy Framework*** 1. Low carbon plan to reach the target for Bristol to be Carbon Neutral by 2050 2. Plan to be reviewed and refreshed every three years to provide a continuous process of improvement 3. Provide continuity of energy supply
XVII. *Adaptation & resilience framework for the Bristol Avon catchment* 1. Greater integration of actions across sectors and political boundaries working at a catchment scale 2. Engaging with other key strategic planning organisations and infrastructure providers to understand the interdependent risks and opportunities and deliver cross-sectoral	***XVIII. Clean Air for Bristol*** 1. Monitoring to retrieve pollutant data, such as for oxides of Nitrogen and particulate matter 2. Declare Air Quality Management Area within worst affected areas and suggest actions to combat this 3. Develop Clean Air Zones and charge the worst polluting vehicles and improve air quality 4. Improve walking, cycling and bus usage

adaptation actions in spatial planning at a catchment scale 3. Deliver multi-beneficial outcomes from collaborative investments from regional natural capital distributed to multiple locations 4. Ensure strong regional economy and enduring infrastructure supported by sustainable agriculture and resilient natural capital 5. Plan an integrated way for the long-term resilience of the WoE region's natural resources	5. Work with bus operators to clean up the bus fleet 6. Ensure BCC fleet of vehicles is clean, by using electric pool cars, some electric vans, some other ultra-low emission vehicles (ULEVs) and providing training for drivers 7. Work with providers to increase the number of EV charge points and implement the Metrobus rapid transit service 8. Plant 50,000 trees 9. The MetroWest project will improve existing rail provision across the sub-region, including the opening of new stations and increased frequency on local lines. 10. Large-scale investment in walking and cycling through the Cycle Ambition Fund which is creating new routes and improving existing infrastructure. 11. MetroBus, a rapid public transport system that will provide an express service to key destinations in the area using a combination of segregated busways and lanes, will use low emission vehicles. 12. Ensuring the council fleet vehicles are modernised to reduce pollution by replacing out of date diesel vehicles. This being supported by a £7 million project to provide over 200 more public and business charging points across the city region. It will also enable people to buy new electric cars with confidence that they can charge them. 13. Increasing the proportion of electric pool cars available for council employees to use on city trips. 14. Changes to Taxi Licencing Policy to improve taxi fleet emissions 15. The whole of Bristol is a smoke control area (SCA) which aims to ensure emissions from solid fuel are controlled to some extent

4 Local workshops

4.1 Introduction

Within the task 5.2 two workshops have been proposed to be held in each city (Lisbon, Barcelona and Bristol) in order to discuss about the problem characterization and the adaptation strategies identification. Common workshop structures were proposed for each city, although they were slightly adapted according to their specific needs. In order to organize properly the workshops, a coordinator for each city was named to maintain a direct communication with the WP5 leader. The main structures were the following:

Workshop 1 (Duration: 4 hours)

1. Giving context: The coordination explained in depth the WP5 progress and the specific task 5.2 approach. Also the Hazur® assessment and sectorial model results were presented for each specific city. Finally, the adaptation strategies web-based platform was presented in order to show to the attendees the specific strategies that have been added up to this moment for their city.
2. Partners' discussion (part 1). Specific questions were proposed to be discussed:
    a. Regarding task 5.3 approach:
        i. Do you agree with the proposed approach?
        ii. Would you propose any improvements?
    b. Regarding the strategies so far included in the database (already planned)
        i. Are they appropriate or well described?
        ii. Would you provide any other?
        iii. Do you think the platform should be improved somehow?
3. Partners' discussion (part 2). Specific questions were proposed to be discussed:
    a. Regarding adding new strategies
        i. Do you identify new strategies based on the results from Hazur® and the sectorial models?
    b. Regarding the prioritizing method to select strategies
        i. Would you add any improvements to the proposed prioritization method?
        ii. How the city council prioritizes them currently?
    c. Monetization of intangible co-benefits
        i. Do we have to monetize them?
        ii. Local previous experiences about this issue

Workshop 2 (Duration: 4 hours)

1. Review of Task 5.3 and expected outcomes. The task 5.3 approach was modified from the last workshop, and this new approach was presented in order to give context to the attendees.
2. Presentation of the strategies already identified by the City Council: A detailed description of the strategies and the measures planned by the city council was given.
3. Strategies fact sheet template adequacy: A fact sheet template was proposed to summarize the main information of each strategy, and it was presented in the workshop.

4. Discussion: Two main discussions were proposed in this part:
    a) Discussion about the strategies identified and a final list proposal
    b) Selection of strategies to include in the models

Based on this common structures for the workshops, following the main conclusions for each workshop are presented.

4.2 First local workshop minutes

4.2.1 Barcelona

The first workshop in Barcelona was held on the 5th of July 2018, and 16 people attended it from different Spanish entities: Barcelona City Council, BCASA, Cetaqua, Aquatec, Opticits and IREC.

Figure 9. Room where the first workshop in Barcelona was held.

The main concerns arisen from the discussion were the following:

- The way to **extract conclusions based on the Hazur® assessment**.
- The **strategies** currently included in the web-based platform are **quite general**.
- Some **improvements** for the web-based **platform** are necessary.
- At least **one new strategy** should be proposed **based on each model result**.
- **Barcelona CC process to prioritize strategies** based on 4 issues: **1) Economic, humans and technical costs; 2) Number of affected citizens 3) Effect upon the avoided impact 4) Implementation deadline: short, middle or long term**.
- **Co-benefits**: the **time variable** is necessary in order to monetize them.

4.2.2 Lisbon

The first workshop in Lisbon was held on July 2018 the 12th, and 20 people attended it from different Portuguese entities: AdTA, CML, EDP, Hidra, and LNEC.

Figure 10. Room where the first workshop in Lisbon was held.

The main concerns arisen from the discussion were the following:

- The **method** for pre-selection of strategies is **not clear**
- The **problem statement is missing** at the beginning
- Sectorial models: **some strategies may not being modelled**
- It is not clear where the **results of the Hazur® post-strategies assessment** are taken into account.
- Political **constrains** and pre-existing **commitments** can **prevail over other methods in the final decision for strategies selection**
- Co-benefits **monetization**: **too complex** to be applied by the organizations.
- Time **horizon of analysis**: Same for all the strategies according to the organizations purposes

4.2.3 Bristol

The first workshop in Bristol was held on the 13th of September 2018, and 6 people attended it from different British entities: Bristol City Council, University of Exeter, Wessex Water and Urban DNA.

Figure 11. Workshop venue. Bristol City Council, 100 Temple Street, Bristol, BS1 6AG

The main concerns arisen from the discussion were the following:

- Some point will be discussed with Opticits in order to **enhance the Hazur® assessment in Bristol**.
- The **strategies** put forward are **appropriate but too generic determine their estimated cost of implementation.**
- **Cost benefit** ratios concluded as **the most appropriate way of prioritisation**.
- **Co-benefits**: many aspects, especially those socially related, are **very difficult to quantify** in monetary terms.
- **Excessive detail** is involved in establishing the **Co-benefits** of the strategies.
- More **specific actions** or interventions could be **more easily quantified**.
- Further methods and ideas to enhance the Hazur® assessment in Bristol have been considered.

4.3 Second local workshop minutes

4.3.1 Barcelona

The second workshop in Barcelona was held on the 4th of March 2019, and 13 people attended it from different Spanish entities: Barcelona City Council, BCASA, Cetaqua, Aquatec, Opticits and IREC.

Figure 12. Room where the second workshop in Barcelona was held.

The workshop started with a presentation of the Task 5.3 approach and the expected outcomes in order to give the attendees the context. Following, the strategies already identified by the City Council (i.e. the ones included in the Barcelona Climate Plan) were presented. In the context of the RESCCUE project not all the Climate Plan strategies were considered because the focus of this project is climate adaptation, thus all the strategies focused on mitigation were excluded from this list. Not only the strategies but also the measures that form the strategies were explained in detail. The presence of members from the City Council among the attendees was really fruitful and their contributions were essential for all of us to understand the purpose of some strategies. Finally, the fact sheet template

developed for gathering the main information for each adaptation strategy was presented to the attendees.

Once reached the discussion part, it was decided not to split the attendees into three groups as planned. The number of people was lower than the expected (i.e. some could not finally attend the workshop), and instead of splitting into two groups a plenary discussion was agreed to be carried out. Firstly, the measures of each strategy from the preliminary list (11 strategies) (i.e. the ones selected from the Barcelona Climate Plan) were analysed and filtered those in which the RESCCUE results could contribute (highlighted in blue in the list presented in Table 9). It was agreed that most of the Climate Plan Strategies are more social-oriented rather than urban services-oriented, therefore these are not totally on the focus of RESCCUE project. However, some the RESCCUE results could even contribute to some specific measures which, as mention previously, were identified and their description was completed by adding the specific RESCCUE contribution. These existing measures in which RESCCUE could contribute will be further described by adding the specific RESCCUE contribution.

On the other hand, the preliminary strategies list (11) was complemented with four strategies more, formed by measures directly identified by the RESCCUE results. In addition, the fact sheet to describe each strategy was agreed by all the attendees.

4.3.2 Lisbon

The second workshop in Lisbon was held on the 11th of March 2019, and 17 people attended it from different Portuguese partners: LNEC, Câmara Municipal de Lisboa, Águas do Tejo Atlântico, EDP and HIDRA.


Figure 13. Room where the second workshop in Lisbon was held.

The workshop started with a presentation of task 5.3 including the purpose and objectives of the workshop. The workshop was divided in two parts: 1st Giving the context and 2nd Partners discussion.

In the first part, presentations included:

1. An overview of the methodology proposed to prioritize measures and adaptation strategies, problem characterization and description.
2. Overall resilience assessment results for Lisbon from the application of the RESCCUE RAF APP.
3. Results of the pre-assessment and the assessment of Lisbon resilience, carried out with the Hazur tool, with focus on the services and infrastructures under analysis, their autonomy, redundancies, cascading effects and interdependencies. Other services

outside Hazur tool have been identified. The climate change driven impacts under study and their consequences in Lisbon, including cascading effects, were explained.

4. Results of sectorial models for the current scenario. Explanation about the three level approach (city wide – Alcântara drainage basin – Lisbon downtown catchment) and the details of the corresponding results and limitations were explained. 1D/2D urban drainage models results for Lisbon were presented. Flooding hazard maps were showed. The results of the integrated flooding-electrical, flooding – transport and flooding - waste models were presented. In the integrated flooding-electrical model measures were taken after flooding events were explained, mainly related with the underground transformation stations that are located in city downtown.
5. The WP5 web-based platform was presented and the identified measures and strategies were shown as an example, as well as the specific fields. The selected ones for Lisbon were explained with detail. The method and mechanisms for assessing the benefits of a strategy composed by several measures. Exchange of ideas about the web-based platform: access only to the data, which could be exportable for use in other tools.

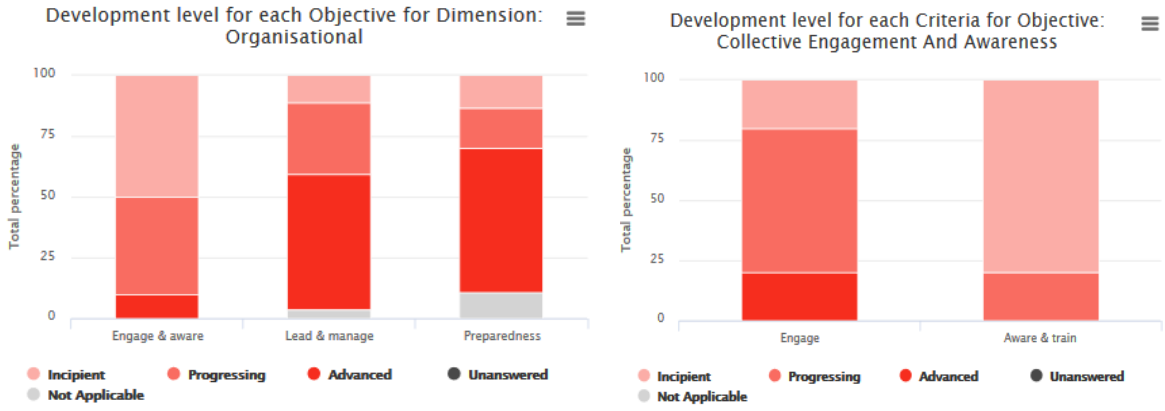
In the second part of the workshop, discussion on new strategies to respond to results of results from sectorial models, HAZUR and RAF application to Lisbon lead to the identification of 10 new strategies.

An important issue discussed was the use of the RAF results to support the definition of strategies. All participants found it to be essential to be integrated within the approach proposed to WP5. Proposal to this was sent to the WP5 coordination. In the next section illustration of the results to Lisbon is presented.

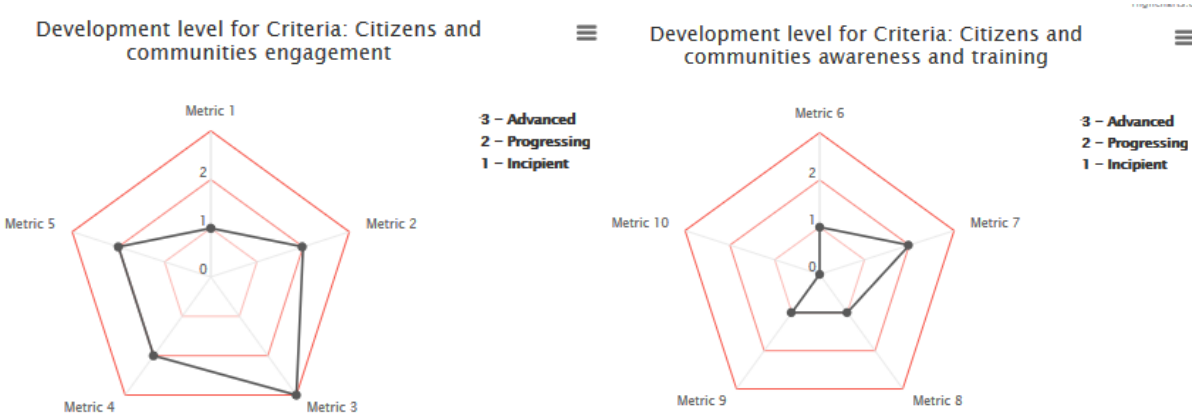
RAF tool results for Lisbon

Regarding RAF tool results for Lisbon some strategies could be identified. RAF can contribute to the identification of cities strategies through the observation of main graphs in results.

Choosing the graphs by dimension, in organisational dimension the *Collective engagement and awareness* is the objective that seems to have more room for improvement. To see more details and the criteria in question, the results should now be seen by objective.



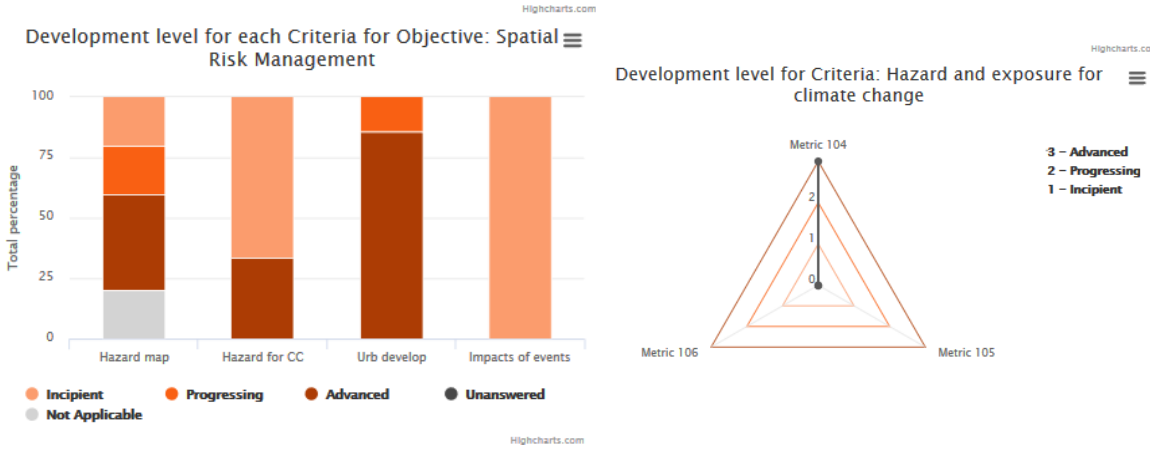
In this example, both criteria have room for improvement. In case of *Citizens and communities engagement*, could be developed a strategy related to the improvement of citizen and organisations engagement. The *Citizens and communities awareness and training* is the criteria with more room for improvement. Metrics within this criteria have a connection with strategy S014 for Lisbon as the need of identification of risk areas inside the municipality are related to the *Knowledge of "most probable" risk scenario and knowledge of key response and preparation step* metric, classified as incipient in her progress.



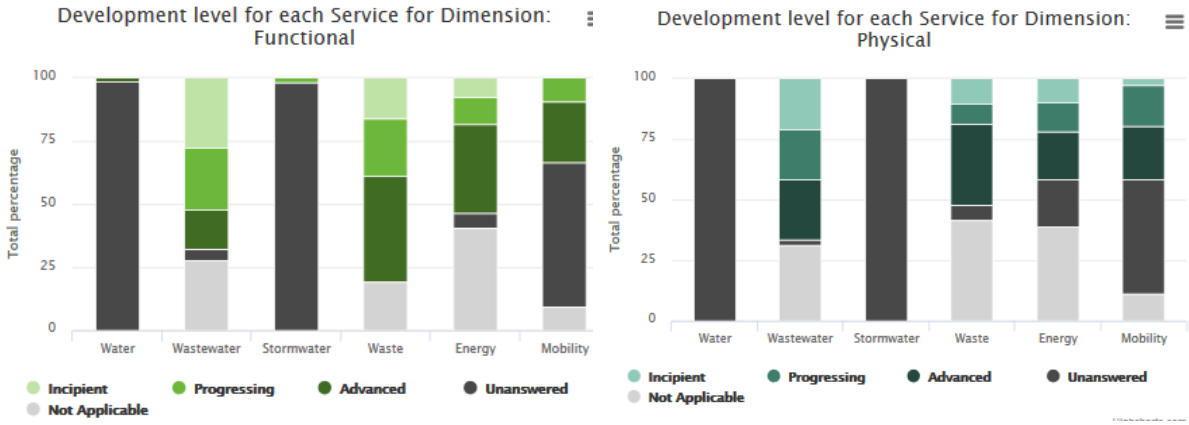
Other strategies could be developed regarding drills implementation, evaluation of campaigns efficiency and the use of social networks.

Spatial dimension seems to have several opportunities for improvement. In this dimension, the *Spatial risk management* objective is the one with more room for improvement. Regarding this objective, there are two criteria whose metrics could be improved and therefore, more strategies could be developed. However, the incipient and not applicable metrics are related to the climate change scenarios and will be answered only in the RAF 3rd stage, therefore no strategies suggestions can be made at this time for this dimension.

Even without a complete assessment, some metrics from *General hazard and exposure mapping* criteria have a connection with strategy S014 for Lisbon since they are about risk assessment and risk maps.



In Functional and Physical dimension there is a service (water) that has no given answers. This could lead to a new strategy, based on the engagement of the utilities and the engagement of specific departments.



4.3.3 Bristol

The second workshop in Barcelona was held on the 1st of March 2019, and 6 people attended it from different British entities: Barry Evans, Albert Chen, Mike Gibson, John Stevens, Rob Henderson, Graham Colclough.

Figure 14. Room where the second workshop in Bristol was held

Barry Evans presented the slides to the others along with showing templates and examples of work that has already been carried out within Barcelona. As the group within this workshop was comparatively smaller than that of Barcelona we took a different track in discussing the selection of adaptation measures:

One caveat when selecting adaptation measures to analyses within the context of RESCCUE was related to the cost and time of re-running flood models with measures in place. For this

reason we decided to try to focus the majority of selected measures on ones that can based on further analysis of pre-existing flood model data or methods of managing risks and assets accordingly. In addition to this caveat the number of adaptation measures selected were chosen as such to ensure that each of the modelled services within RESCCUE would receive benefit from one or more of the selected measures employed.

Proposed measures:

1. Learn from real-life flooding by recording and investigating events.
2. Create and maintain Flood Risk Asset Registers to identify key flood risk assets and who is responsible for their maintenance.
3. Identify high-risk areas by conducting studies involving flood modelling analysis. – Additional flood model runs may be required for this one measure
4. Develop Community Flood Plans.
5. Build riverside flood defence walls.

5 Conclusions

The present report contains the results obtained after the deployment of the task 5.3, covering resilience and adaptation strategies ready for market uptake. The main finding of D5.2 are a) **the development of a framework to promote resilience strategies, which includes the creation of a measures database** after the description of the main problems of the three research sites (Lisbon, Barcelona and Bristol), b) **the establishment of a methodology to prioritise strategies and measures considering economic, technical and social aspects**, and c) the description of the workshops carried out.

Throughout the developing period of task 5.3, two workshops have been held in each city. The aim of these workshops was to agree on a proper methodology to prioritize strategies and also to identify a list of adaptation strategies needed according to the climate impacts that threaten the cities today and to be prepared for the future ones. Therefore, together with the minutes of the different workshops, this report proposes the methodology of adaptation strategies prioritization that was agreed in the workshops, and also a comprehensive list of strategies is presented according to the problems characterization of each city.

The proposed methodology distinguishes between two approaches, one related to urban services-oriented strategies (identified through RESCCUE project), and another one focused on social-oriented strategies (out of the scope of this project). The second group is also included in the strategies list for each city and their origin is a City Council identification to address citizens' vulnerabilities and welfare. The first group is identified in RESCCUE according to the obtained results for both scales: detailed (i.e. sectorial models and RAF), and holistic (Hazur® assessment). Moreover, a direct contribution from the tasks related to the Resilience Action Plan (RAP) development has been undertaken in order to identify and fulfil the strategies list provided herein.

Both approaches are based on the three key variables previously described in D5.1 – investment, city recovery time, and co-benefits. The first method to assess urban services-oriented strategies, is based on a multiple-step process, composed by a cost effectiveness analysis (CEA) and a cost-benefit analysis (CBA). The method proposed for the social-oriented strategies refers to a multi-criteria analysis.

The analyses that form both approaches will be allocated in different deliverables, according to the nature of each type of analysis. The approach 1, formed by the CEA and the CBA, will present the CEA in WP4 (D4.5) because the Hazur® assessment is provided in this WP4, and the CBA will be presented in WP3 (D3.5) because the damages assessment for the different strategies scenarios is presented in this WP3. The sector models will be run by considering the effects of the adaptation measures, and the obtained results will be presented in WP2 (D2.5). Regarding social-oriented strategies, the approach 2 (multi-criteria analysis) has to be utilized, and it will be described in D5.3.

REFERENCES

Altava V., Barrera A., Amaro J., Bernolas M., Prohom M., Sairouni A., Cunillera J. (2015): Escenaris climàtics regionatlitzats a l'Àrea Metropolitana de Barcelona (Projecte ESAMB), SMC (Servei Meteorològic de Catalunya)

Adusei-Asante, K. & Hancock, P. (2016). Measuring Policies with the Social Impact Assessment Framework: Opportunities and Challenges.

Barcelona Regional, 2017. Escenaris climàtics futurs. Servidor de mapes downscaling metropolità. Barcelona City Hall. Link: https://www.bcnregional.com/ca/projects/environment/servidorde-mapes-downscaling-metropolita/ (Last accessed Jan 24th 2019)

Becker, H. (2001). Social impact assessment. European Journal of Operational Research 128, 311-321.

Berger, T. R. (1983). Resources, development, and human values. Impact Assessment 2, 129-147.

Bergold, J. & Thomas, S. (2012). Participatory research methods: A methodological approach in motion. Historical Social

Burdge, R. J. (2003). The practice of social impact assessment – background. Impact Assessment and Project Appraisal 21, 84-88.

Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S. & Roberts, D. (2013): Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment & Urbanization. International Institute for Environment and Development (IIED). Vol 25(1): 139–156.

Chung, E.-S. & Kim, Y (2014): Development of fuzzy multi-criteria approach to prioritize locations of treated wastewater use considering climate change scenarios. Journal of Environmental Management 146, 505-516.

Department of Communities and Local Government (2009): Multi-criteria analysis: a manual. West Yorkshire.

Duinker, P. N. & Greig, L. A. (2006). Scenario analysis in environmental impact assessment: Improving explorations of the future. Environmental Impact Assessment Review 27, 206-219.

Dyson, R. (2002). Strategic development and SWOT analysis at the University of Warwick. European Journal of Operational Research 152, 631-640.

Erdmann, L. & Hilty, L. M. (2010). Scenario analysis. Journal of Industrial Ecology 14, 826-843.

Esteves, A. M., Franks, D., & Vanclay, F. (2012). Social impact assessment: the state of the art. Impact Assessment and Project Appraisal 30, 34-42.

Franks, D. M., Brereton, D., & Moran, C. J. (2010). Managing the cumulative impacts of coal mining on regional communities and environments in Australia. Impact Assessment and Project Appraisal 28, 299-312.

Fuamba, M., Coulais, C., & Bertrand, H. (2011). An innovative method for selecting efficient Best Management Practices. 12th International Conference on Urban Drainage. Porto Alegre/Brasilien.

Füssel, H.J. & Klein, J.T. (2006): Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change 75, 301–329.

Glass, J. R., Kruse, G. H., & Miller, S. A. (2015). Socioeconomic considerations of the commercial weathervane scallop fishery off Alaska using SWOT analysis. Ocean & Coastal Management 105, 154-165.

Guijt, I. (2014). Participatory approaches. Methodological Briefs: Impact Evaluation 5, UNICEF Office of Research, Florence.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., & Jax, K. (2013). Benefits and limitations of the ecosystem services concept in environmental policy and decision making: some stakeholder perspectives. Environmental Science & Policy 25, 13-21.

Helms, M. M. & Nixon, J. (2010). Exploring SWOT analysis – where are we now? A review of academic research from the last decade. Journal of Strategy and Management 3, 215-251.

Hwang, C.-L. & Yoon, K. (1981): Multiple Attribute Decision Making Methods and Applications A State-of-the-Art Survey. Springer Verlag. 128-140.

Jato-Espino, D., Rodriguez-Hernandez, J., Andrés-Valeri, V., & Ballester-Muñoz, F. (2014). A fuzzy stochastic multi-criteria model for the selection of urban pervious pavements. Expert Systems with Applications (41), 6807-6817.

Joseph, R., Proverbs, D. & Lamond, J. (2016): Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures A conceptual framework for residential. Structural Survey Vol. 32 No. 2, 102-122.

Kanji, N. & Greenwood, L. (2001). Participatory approaches to research and development in IIED: Learning from experience. IIED.

Karagiorgos, K., Thaler,T. Hübl, J. Maris, F. & Fuchs, S. (2016): Multi-vulnerability analysis for flash flood risk management. Nat Hazards 82, 63–87.

Kok, M., Lüdeke, M., Lucas, P., Sterzel, T., Walther C., Janssen, P., Sietz D. & de Soysa I. (2016): Reg Environ Change 16, 229–243.

Kosow, H. & Gaßner, R. (2008). Deutsches Institut für Entwicklungspolitik gGmbH (Ed.): Methods of future and scenario analysis: Overview, assessment, and selection criteria.

Krysanova, V., Dickens, C., Timmerman, J., Varela-Ortega, C., Schlüter, M., Roest, K., ... & de Pedraza Carrera, J. (2010). Cross-comparison of climate change adaptation strategies across large river basins in Europe, Africa and Asia. Water Resources Management 24, 4121-4160.

Liu, X., Vedlitz, A., & Shi, L. (2014). Examining the determinants of public environmental concern: Evidence from national public surveys. Environmental Science & Policy 39, 77-94.

López, H. (2018). A Multi-Criteria Analysis for the city of Gothenburg (Doctoral dissertation or master's thesis). University of Gothenburg.

McCombes, L., Vanclay, F., & Evers, Y. (2015). Putting social impact assessment to the test as a method for implementing responsible tourism practice. Environmental Impact Assessment Review 55, 156-168.

McLeod, E., Szuster, B., Tompkins E. L., Marshall, N., Downing, T., Wongbusarakum, S., Patwardhan, A. Hamza, M., Anderson C., Bharwani, S., Hansen, L. & Rubinoff, P. (2015): Using Expert Knowledge to Develop a Vulnerability and Adaptation Framework and Methodology for Application in Tropical Island Communities. Coastal Management, 43, 365–382.

Meng, M., Jing, K., & Mander, S. (2016). Scenario analysis of CO_2 emissions from China's electric power industry. Journal of Cleaner Production 142, 3101-3108.

Metternicht, G., Sabelli, A. & Spensley, J. (2014): Climate change vulnerability, impact and adaption assessment. Lesson from Latin America. International Journal of Climate Change Strategies and Management, 6, 442-476.

Montazar, A., & Zadbagher, E. (2010). An analytic hierarchy model for assessing global water productivity of irrigation networks in Iran. Water Resources Management, 24 (11), S. 2817-2832.

Noi, L. V. T. & Nitivattananon, V. (2015). Assessment of vulnerabilities to climate change for urban water and wastewater infrastructure management: Case study in Dong Nai river basin, Vietnam. Environmental Development 16, 119–137.

OECD (2018), *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use*, OECD Publishing, Paris.

Pickton, D. W. & Wright, S. (1998). What's swot in strategic analysis? Strategic change 7, 101-109.

Postma, T. J. & Liebl, F. (2005). How to improve scenario analysis as a strategic management tool? Technological Forecasting & Social Change 72, 161-173.

Rad, L. K., Ghamgosar M. & Haghyghy, M. (2012): Multicriteria Decision Making Based on TOPSIS Method in Drought Zoning: A Case Study of Gilan Province. World Applied Programming, Vol (2), No (2), 81-87.

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. Biological Conservation 141, 2417-2431.

Ribalaygua J, Torres L, Pórtoles J, Monjo R, Gaitán E, Pino MR. 2013. Description and validation of a two-step analogue/regression downscaling method. Theoretical and Applied Climatology 114: 253-269, doi: 10.1007/s00704-013-0836-x.

Saaty, T. L. (1986): Axiomatic foundation of the analytic hierarchy process. Management Science 32 No. 7, 841–855.

Saaty, T. & Sodenkamp, M. (2010): The analytic hierarchy and analytic network measurement process: The measurement of intangibles. In: Zopounidis, C., Pardalos, P. M. (Hrsg.):

Handbook of Multicriteria Analysis. Applied Optimization 103. Springer-Verlag Berlin Heidelberg, 91–166.

Safavi, H. R., Golmohammadi, M. H., & Sandoval-Solis, S, (2016): Scenario analysis for integrated water resources planning and management under uncertainty in the Zayandehrud river basin. Journal of Hydrology 539, 625-639.

Sigurðardóttir, S., Stefánsdóttir, E. K., Condie, H., Margeirsson, S., Catchpole, T. L., Bellido, J. M. & Uhlmann, S. S. (2015). How can discards in European fisheries be mitigated? Strengths, weaknesses, opportunities and threats of potential mitigation methods. Marine Policy 51, 366-374.

Slocum, N. (2003). Participatory methods toolkit. A practitioner's manual. King Baudouin Foundation.

The Interorganizational Committee on Guidelines and Principles for Social Impact Assessment (1995). Guidelines and principles for social impact assessment. Environmental Impact Assessment Review 15, 11-43.

Van den Berg, M., van Gils, P.F., P.F. de Wit, P.F., Schuit, A.J. (2008) Economic evaluation of prevention Fourth report on the cost-effectiveness of preventive interventions. Centrum voor Volksgezondheid Toekomstverkenningen

Van Moeffart, D. (2002): Multi Criteria Decision Aid in Sustainable Urban Water Management. Scandia Consult Providence.

Vanclay, F. (2002). Conceptualizing social impacts. Environmental Impact Assessment Review 22, 183-211.

Vanclay, F., and Esteves, A.M. (2011). Current issues and trends in social impact assessment. In: F. Vanclay and A.M. Esteves, eds. New directions in social impact assessment: conceptual and methodological advances. Cheltenham: Edward Elgar, 3–19.

Victor, P. (2012). Growth, degrowth and climate change: A scenario analysis. Ecological Economics 84, 206-212.

Zarafshani, K., Sharafi, L., Azadi, H. & Van Passel, S. (2016): Vulnerability Assessment Models to Drought: Toward a Conceptual Framework. Sustainability, 8, 588.

RESCCUE

RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

ANNEXES

A1. Terms Glossary

Accommodation approach: The accommodate approach involves the continued occupancy and use of vulnerable zones by increasing society's ability to cope with the effects of extreme events. (source: Linham M. M. and Nicholls R. J. 2010, original source: IPCC CZMS, 1990)

Actor: A person linked to a specific action within the resilience action, but who does not participate in the resilience implementation process. (source: Hazur® terminology)

Adaptation (to climate change): The process of adjustment to actual or expected climate, and its effects. See also Autonomous Adaptation, Evolutionary Adaptation, Incremental Adaptation and Transformative Adaptation. (source: IPCC 2014a)

Adaptation assessment: The practice of identifying options to adapt to climate change and evaluating them, in terms of criteria such as availability, (co-) benefits, costs, effectiveness, efficiency and feasibility. (source: adapted from IPCC 2014a)

Adaptation measures: are specific interventions to address a specific climate risk. This can be a measure that for example

Prevents a hazardous event from happening

Reduces or deflects the impact of a hazardous event

Improves recovery after a hazardous event has happened

Measures can be technical, infrastructural, but also legal, economical of social. So a measure could be building a dam, increasing the price of drinking water or raising awareness of flood risks. (Source: BINGO EU Project)

Adaptation Options: The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of actions that can be categorized as structural, institutional, or social. (source: IPCC 2014a)

Adaptation strategies: are a collection of measures linked to specific risks and their impacts. The strategy provides a framework of which the measures are the practical outcome. A strategy consists of:

Identification of the risks and their impacts

Strategic goals that need to be achieved

Measures that help achieve those goals by addressing the risks

Implementation plan for the measures

The analysis in this phase will be based on the individual measures, but the outcome will be beneficial in developing the strategies. (Source: BINGO EU Project)

Adaptive capacity (or adaptability): The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. (source: IPCC 2014a)

Cascading Effects: A sequence of events in which each one produces the circumstances necessary for the initiation of the next. See also Consequence Analysis (source Allaby 2004). Or a sequence of events in which each individual event is the cause of the following event; all the events can be traced back to one and the same initial event. (source: Rome *et al.* 2015)

Climate: Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. (source: IPCC 2013)

Climate Change: Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. (source: IPCC 2013)

Climate Projection: A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. (source: IPCC 2013)

Climate Model: A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.(source: IPCC 2013)

Climate System: The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. (source: IPCC 2013)

Co-benefits: The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices, among other factors. Co-benefits are also referred to as ancillary benefit. (source: Allaby 2004)

Consequence: The outcome of an event affecting objectives. (source: ISO/IEC 27000: 2014 and ISO 310000: 2009)

Consequence Analysis: Consequence Analysis is estimation of the effect of potential hazardous events. (source: Australian Emergency Management Glossary (1998))

Contextual Vulnerability: A present inability to cope with external pressures or changes, such as changing climate conditions. Contextual vulnerability is a characteristic of social and ecological systems generated by multiple factors and processes. (source: IPCC 2014a)

Coping Capacity: The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term. (source: IPCC 2014a)

> *Further definition*: The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters. (Source: UNISDR 2009)

Critical Infrastructure (CI): An asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions. Organizations and facilities that are essential for the functioning of society and the economy as a whole. (source: European Commission: Council Directive 2008/114/EC ISO/IEC TR 27019:2013)

Critical Infrastructure (CI) Dependency: CI dependency is the relationship between two (critical infrastructure) products or services in which one product or service is required for the generation of the other product or service. (source: Rome et al 2015)

Critical Infrastructure (CI) Element: Part of a CI. It can have sub-elements. (source: Rome et al 2015)

Critical Information Infrastructure (CII): Critical information infrastructures ('CII') should be understood as referring to those interconnected information systems and networks, the disruption or destruction of which would have serious impact on the health, safety, security, or economic wellbeing of citizens, or on the effective functioning of government or the economy. (source: OECD Recommendation of the Council on the Protection of Critical Information Infrastructures C(2008)35)

Critical Infrastructure (CI) Interdependency: The mutual dependency of products or services. (Source: ACIP 2003)

Critical Infrastructure Protection (CIP): All activities aimed at ensuring the functionality, continuity and integrity of critical infrastructures in order to deter, mitigate and neutralise a threat, risk or vulnerability. (source: Council Directive 2008/114/EC)

Critical Infrastructure (CI) Sector: Economic sectors considered critical. (source: Rome et al 2015)

Damage classification: Damage classification is the evaluation and recording of damage to structures, facilities, or objects according to three (or more) categories. (source: UN Department of Humanitarian Affairs, 1992)

Decision: The result of making up one's mind regarding a choice between alternatives (source: Wijnmalen et al 2015)

Decision Support: The structure process of activities that support decision makers and other stakeholders in coping with and resolving problems they are faced with. (source: Wijnmalen et al 2015)

Direct Damage: relates to damage that results directly from a defined impact; for example a flood event could cause direct physical damage to an infrastructure due to the immediate physical contact of flood water with humans, property and the environment. The terms 'loss' and 'damage' are used synonymously in the literature.

Disruption: Incident, whether anticipated (e.g. hurricane) or unanticipated (e.g. a blackout or earthquake) which disrupts the normal course of operations at an organization location. (Source: ISO/PAS 22399:2007 Societal security - Guideline for incident preparedness and operational continuity management.)

Drivers: Drivers are aspects which change a given system. They can be short term, but are mainly long term. Changes in both the climate system and socioeconomic processes including adaptation and mitigation are drivers of hazards, exposure, and vulnerability. Drivers can, thus, be climatic or non-climatic. Climatic drivers include: warming trend, drying trend, extreme temperature, extreme precipitation, precipitation, snow cover, damaging cyclone, sea level, ocean acidification, and carbon dioxide fertilisation. Non-climatic drivers include land use change, migration, population and demographic change, economic development. (source: based on IPCC 2014b (SPM))

Efficiency: The good use of time and energy in a way that does not waste any. (source: http://dictionary.ca mbridge.org/dictionary/english/efficiency)

Effectiveness: The ability to be successful and produce the intended results (source: http://dictionary.ca mbridge.org/dictionary/english/effectiveness)

Ensemble: A collection of model simulations characterizing a climate prediction or [climate] projection. (source: IPCC 2013)

European Critical Infrastructure: Critical infrastructure located in Member States the disruption or destruction of which would have a significant impact on at least two Member States. The significance of the impact shall be assessed in terms of cross-cutting criteria. This includes effects resulting from cross-sector dependencies on other types of infrastructure. (source: Council Directive 2008/114/EC)

Event: Occurrence or change of a particular set of circumstances.

> An event can be one or more occurrences, and can have several causes.
>
> An event can consist of something not happening.
>
> An event can sometimes be referred to as an "incident" or "accident". (source: CIPedia® 2015 based on ISO/PAS 22399:2007 and ISO/IEC 27000:2014)

Evolutionary Adaptation: For a population or species, change in functional characteristics as a result of selection acting on heritable traits. The rate of evolutionary adaptation

depends on factors such as the strength of selection, generation turnover time, and degree of outcrossing (as opposed to inbreeding). (source: IPCC 2014a)

Exposure: The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected (source: IPCC 2014a)

Extreme Weather Event: An extreme weather event is an event that is rare at a particular place and time of year. (source: IPCC 2013)

Flood Risk: The risk associated with flood events in a certain region and in a certain time period. (source: PEARL EU Project)

Green Infrastructure: Broadly defined as a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings. Note: Green infrastructure may incorporate both landscape and water features, the latter of which may be termed 'blue infrastructure'. Other terms include 'green-blue infrastructure' and 'green and blue infrastructure'. (Source: European Commission 2013b.)

Grey Infrastructure: Familiar urban infrastructure such as roads, sewer systems and storm drains is known as 'grey infrastructure'. Such conventional infrastructure often uses engineered solutions typically designed for a single function. (source: Parliamentary Office of Science & Technology 2013)

Hazard: The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. The term hazard usually refers to climate-related physical events or trends or their physical impacts. (source: IPCC 2014a)

Impact Chains: Impact chains permit the structuring of cause - effect relationships between drivers and/or inhibitors affecting the vulnerability of a system. Impact chains allow for a visualization of interrelations and feedbacks, help to identify the key impacts, on which level they occur and allow visualising which climate signals may lead to them. They further help to clarify and/or validate the objectives and the scope of the vulnerability assessment and are a useful tool to involve stakeholders. (BMZ 2014)

Impact: Effects on natural and human systems. The term impact is used primarily to refer to the effects on natural and human systems of extreme weather and events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes of hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Note: Impacts are also referred to as consequences and outcomes (Adapted from IPCC 2014a). Or the direct outcome of an event. (source: CIPedia® 2015)

Improvement area: domain to be improved to increase the resilience of a specific urban area. For example: Improving the citizen service/Improving mobility in the coastal district of the city

Improvement project: specific action belonging to an improvement area that allows to reduce the recovery costs (political, economic, social, technological, environmental, and legal) in an urban area, thus increasing its resilience. For example: Setting up a free hotline for citizens/New roundabout in city access XY

Incident: Event that might be, or could lead to, an operational interruption, disruption, loss, emergency or crisis. (source: ISO/PAS 22399: 2007)

Incremental Adaptation: Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale. (source: IPCC 2014a)

Infrastructure: Any installation that can be situated geographically, which functioning is key to the provision of a service. [Examples: Waste water treatment plant, power transformer, a hospital.]. (source: Hazur® terminology)

Intensity: The quality of being intense. The measurable amount of a property, such as force, brightness, or a magnetic field. (source: Oxford English Dictionaries https://en.oxforddi ctionaries.com/definition/intensity)

Interdependence: relationship between different services or infrastructures that is given when one service or infrastructure (donor) fails and makes fail another one (the receptor). [Example: waste water treatment plant X fails if Y power transformer fails.]. (source: Hazur® terminology)

Likelihood: The chance of a specific outcome occurring, where this might be estimated probabilistically. (source: IPCC 2014a)

Maladaptation: Actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future. (source: IPCC 2014a)

Mitigation: The lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability. (source: IPCC 2012)

Operators Group: Group formed by the steering group and the management of significant operators of infrastructure and services in the territory. (source: Hazur® terminology)

Passive Measure: It is a type of measure which does not use energy once it has been implemented. It is normally referred to adaptation measures for buildings indoor environments. (source: Van Hoof et al 2014)

Probability: Measure of the chance of occurrence expressed as a number between 0 and 1 where 0 is impossibility and 1 is absolute certainty. (Source: ISO Guide 73:2009). Or the

likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome and 1 indicating an outcome is certain. (source: The Australian Emergency Management Glossary)

Probabilistic Climate Projections: These are projections of future absolute climate that assign a probability level to different climate outcomes. This projection provides an absolute value for the future climate (as opposed to giving values that are relative to a baseline period) that assign a probability level to different climate outcomes. (source: Adapted from the UK Met Office 2014)

Protection approaches: A protection approach involves defensive measures and other activities to protect areas against flood risk. The measures may be drawn from an array of "hard" and "soft" structural solutions. (source: Linham M. M. and Nicholls R. J. 2010, original source: IPCC CZMS, 1990)

Player: A person linked to the management or the operation of a service or infrastructure in an urban area and engage in the resilience implementation process, including politicians, municipal technical staff and service operators. (source: Hazur® terminology)

Recovery: The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors. (source: UNISDR 2009)

Recovery time: it is Hazur® terminology and means the period of time during which an element (i.e. service or infrastructure) becomes inoperable or is not performing its proper function due to a certain impact (e.g. Flood, heat wave, drought or sea level rise)

Recovery time matrix: it is a matrix which gathers all recovery times of all services or infrastructures (i.e. rows) according to different impacts (i.e. columns). The rank of the matrix will depend on the services/infrastructures and impacts considered when developing the city model through Hazur®. This information is defined at the "what if" matrix of Hazur®

Redundancy: Service of infrastructure that can replace or can be replaced with another service or infrastructure. [Example: a power transformer able to replace another power transformer of the same urban area, a hospital that can accept people that cannot go to their district health center.]. (source: Hazur® terminology)

Reliability: Property of consistent intended behaviour and results. (source: ISO/IEC 27000:2014)

Resilience: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Arctic Council, 2013) (source: IPCC 2014a)

Further definition: 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. (Source: UNISDR 2009)

Responder: Technical or human equipment to mobilize in case of crisis. [Example: a power generator, the police, a psychologist team.]. (source: Hazur® terminology)

Retreat approaches: In the measures context, the retreat approach refers to planned withdraw from the coast or the often inundated areas, rather than an unplanned or forced retreat which is also potentially possible in the face of sea level rise and climate change. (source: Linham M. M. and Nicholls R. J. 2010, original source: IPCC CZMS, 1990)

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. (source: IPCC 2014a)

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. (source: IPCC 2013)

Sector: A part or division, as of a city or a national economy. (Source: American Heritage® Dictionary of the English Language)

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct or indirect. (source: adapted from IPCC 2014a)

Service: Group of activities with the aim of meeting the needs and ensuring the quality of life of the inhabitants of a territory. (source: Hazur® terminology)

Social Infrastructure (Institutional): The social infrastructure includes the humans, organizations and governments that make decisions and form our economy as well as our institutions and policies. (source: Chappin and van der Lei 2014)

Social Infrastructure (Physical): Schools, hospitals, shopping or cultural facilities. (source: unpublished working glossary of UP KRITIS and BSI, 2014)

Source Control Measures: Source control measure means any stormwater management practice designed to reduce and/or slow the flow of stormwater into a combined sanitary and stormwater sewer or a separate stormwater sewer, including, but not limited to, any such practices commonly referred to as Low Impact Development or Best Management Practices. (source: New York City Administrative Code-Section 24-526. 1: Sustainable Stormwater Management)

Stakeholder: Person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity. Note: A decision maker can be a stakeholder. (source: adapted from: ISO 31000:2009)

Steering Group: Group constituted almost entirely of senior administration officials with authority over essential services and infrastructure to ensure resilience in the territory being studied. Responsible for defining the significant operators, territorial resilience objectives, the key processes, and to make major impacts that may occur. (source: Hazur® terminology)

Strategic Group: Group of senior political and managerial leadership of public organizations. It will bring conviction and political action to the project validating performances from a strategic standpoint. (source: Hazur® terminology)

Stressors: Events and trends, often not climate-related, that have an important effect on the system exposed and can increase climate related risk. (Source: adapted from Oppenheimer *et al.* 2014: p. 1048).

Transformative Adaptation: Adaptation that changes the fundamental attributes of a system in response to climate and its effects. (source: IPCC 2014a)

Uncertainty: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. (source: IPCC 2014a)

Urban (Urban Area): Urban 'is a function of (1) sheer population size, (2) space (land area), (3) the ratio of population to space (density or concentration), and (4) economic and social organization.' (Source: Weeks 2010). Or the OECD-EU classification identifies functional urban areas beyond city boundaries, to reflect the economic geography of where people live and work. Defining urban areas as functional economic units can better guide the way national and city governments plan infrastructure, transportation, housing and schools, space for culture and recreation. (source: OECD 2012)

Urban Critical Infrastructure: An asset, system or part thereof located in an urban area which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in an urban area as a result of the failure to maintain those functions. (source: adapted from Council Directive 2008/114/EC)

Urban Critical Infrastructure System: Urban critical infrastructure from a systemic viewpoint. It is part of the urban system and simultaneously part of the national critical infrastructure system. (source: Rome et al 2015)

Urban System: System of urban areas (Urban settlements from a systemic viewpoint) (source: Rome et al 2015)

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Note: Please see contextual vulnerability and outcome

vulnerability. (Source: IPCC 2014a). Or intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence (CIPedia© 2015) OR Weakness of an asset or control that can be exploited by one or more threats. (source: ISO/IEC 27000: 2014)

Vulnerability Index: A metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability. (source: IPCC 2014a)

Wicked Problem: A problem that is categorized by a great number of uncertainties. These include: on the stakeholders involved, the boundaries of the problem, long term organisational developments and responsibilities, amongst others. (Source: adapted from Wijnmalen et al 2015. Please also see Rittel and Webber 1973)