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RESILIENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

D5.5 MULTISECTORIAL RESILIENCE STRATEGIES FRAMEWORK AND STRATEGIES DATABASE DEVELOPMENT (Updated: October 2020)

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

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09/10/2020	v3	Martínez-Gomariz, Eduardo & Guerrero-Hidalga, María	This version contains the revisions proposed by the reviewers.

1. **Changes with respect to the DoA**
   This report was proposed to be elaborated in the last Grant Agreement amendment. This is the description of a new task on the development of a new Web-based strategies platform that has been carried out in WP5 because of the Opticits' termination.

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 D5.5 – "Multisectorial resilience strategies framework and strategies database development (updated: October 2020)" provides an update of the framework related to adaptation strategies in order to make decisions to select them in an effective manner.
   Moreover, a new version of the web-based platform to provide support on the selection of adaptation measures has been developed, and its description has been updated.

4. **Evidence of accomplishment**
   A new web-based application has been developed (http://adaptationstrategies.resccue.eu/). The adaptation measures database is fully open, and no register is requested to visualize them. However, for an entire platform functionality, a sign-up process is required, which will allow users to add new adaptation measures and strategies. Also, the prioritization step-by-step process will be allowed for registered users.

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Tables/Figures Summary

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Executive Summary

The Opticits' termination has affected the WP5 structure, planning and dedicated budget. Because of its termination future uses of Hazur® are not possible, thus the resilience strategies framework has been adapted accordingly. The criteria proposed here to decide which measures to select are an **effectiveness indicator,** the **co-benefits**, the strategies' **estimated cost**, and an indicator related to the **damages and risks reduction** of the adaptation actions. Considering these variables, the proposed prioritization methodology must offer a flexible approach, able to adapt to different urban contexts. The balance between expertise, resources requirements, accuracy, and replicability of results have been important considerations during the design process. The capacity of the methodology to allow for different levels of detail was also considered, due to the diverse data availability, which normally limits the assessment potential. Meeting these requirements was made possible by developing a method that followed the principles of Multicriteria Analysis (MCA), in the sense that it (i) gives relevance to stakeholders' decisions; (ii) uses normalized quantitative and qualitative indicators through a scoring system; (iii) is able to rank options with different goals; and (iv) offers a multi-phase analysis approach.

The framework of the proposed methodology to prioritise adaptation measures is formed by phases that are composed by combinations of assessment methods, ordered from more basic to more detailed assessments. The first stage includes a Cost Efectiveness Analysis (CEA)and co-benefits scoring assessment, whereas the following phase is based on more detailed assessments—risks reduction assessment and Cost- Benefit Analysis (CBA). In addition, the methodology proposes several variables to rank results that help decision-makers to downselect the most suitable measures for their specific policy goals.

Moreover, from a budgetary point of view, new economic resources have been put into the development of a new web-based platform, according to the last grant agreement amendment. It consists on a platform to assist decision makers to select adaptation measures in an effective and efficient manner. In this context, a new Task 5.4 "Web-based platform development to assist to the adaptation measures prioritization" has been added to the WP to develop this new platform. In addition, this Deliverable 5.5 is an update of D5.1 in order to include the new framework approach and the description of the new functionalities of the new platform.

This new platform, in comparison with the initial development described in D5.1, integrates new functionalities and presents a better performance and a more intuitive design for the users to have a greater experience. The initial aim in this WP5 was the development of a regular database to gather climate adaptation measures based on a comprehensive state-of-the-art review and the knowledge of the consortium in climate adaptation for different urban utilities. Both, a greater ambitious and an extra budgetary boost allocated to this new task, have led to a more comprehensive tool which may contribute to the prioritization of adaptation options process at the municipal level.

1 Introduction and RESCCUE general framework

1.1 Overview

This document (D5.5) describes an updated framework to select adaptation measures and a web-based tool to provide support in their prioritisation. It has been developed in the wide context of the RESCCUE Project. The Project deals with climate change in urban areas, so that, with the resilience and potential impacts of extreme events on urban services, like transports, energy production, and water and energy distribution. The project will provide a framework 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 (Manca et al, 2017). This objective must be achieved by implementing new tools and models, suitable for different kinds of city (Lisbon, Barcelona and Bristol), characterized by several climate conditions and pressures. **One of the most important contributions of the Project is the analysis of the interdependencies among the several urban services and the impacts that climate change will generate on each one, giving particular relevance to effects of a failure in one sector and its consequences, in terms of cascade effects, also on the other ones**.

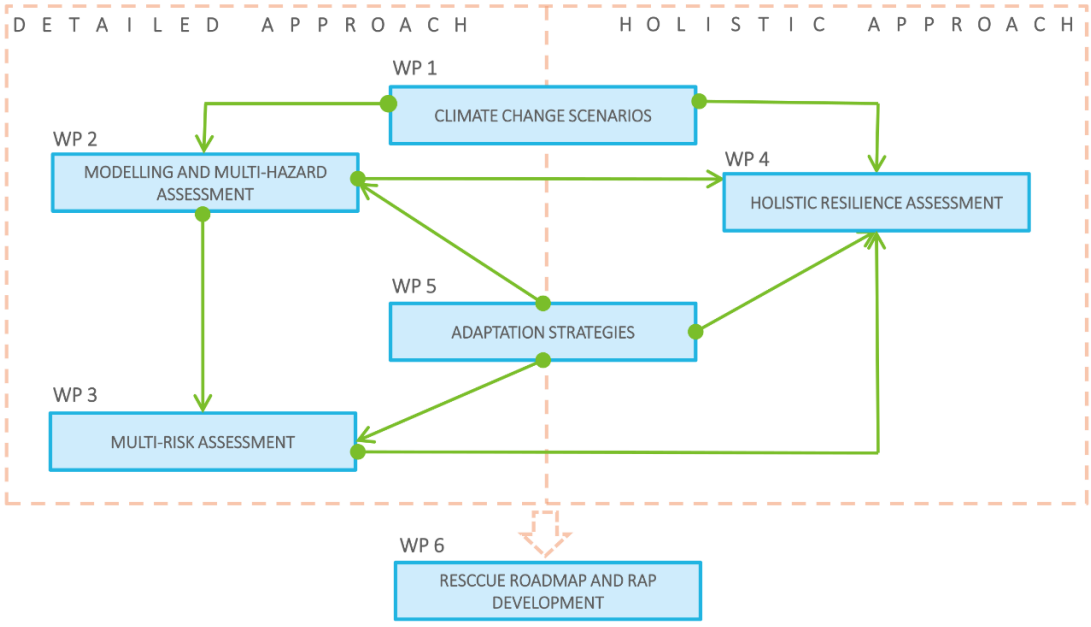

Figure 1. Summary of RESCCUE framework

The detailed knowledge of the behaviour of our urban systems during extreme climate events has been used to characterize the sites and analyse each urban service with special focus on their potential link with extreme climate phenomena.

On the other hand, the analysis of the behaviour and response of strategic urban services and critical infrastructures to specific pressures and drivers related to climate change was conducted through detailed models and software tools. The outputs of these sectorial models were used to assess hazard, vulnerability and risk levels related to the pressures/drivers for current and future scenarios where a large set of adaptation measures were simulated and evaluated in terms of impacts reduction. Afterwards, as a second step, the urban services interdependencies and the cascade effects due to failures or extreme climate events was studied through the Hazur® platform.

The Opticits termination has affected the WP5 structure, planning and dedicated budget. Because of its termination future uses of Hazur® are not possible, thus the resilience strategies framework has been adapted accordingly. Moreover, from a budgetary point of view, new economic resources have been put into the development of a new web-based platform, according to the last grant agreement amendment. It consists on a platform to assist decision makers to select adaptation measures in an effective and efficient manner (section 3). In this context, a new Task 5.4 “Web-based platform development to assist to the adaptation measures prioritization” has been added to the WP to develop this new platform and this Deliverable 5.5 is an update of D5.1 to include the new framework approach (section 2) and the description of the new functionalities of the new platform (section 3).

1.2 Considered hazards for the different sites

Hazards are mainly due to changes in significant climate variables because of climate change. In this section, hazards that jeopardise the cities analysed within this project are briefly described in Table 1.

Table 1. Summary of Hazards for the different sites, based on the diagnosis made by each City Council

Site	Hazards
Lisbon	Heat wave, high temperature, cold wave, low temperature, sea level rise, storm surge, urban flooding, drought, combined sewer overflow (CSO), windstorm, thunderstorm and hail
Barcelona	Rainstorm, heat wave, drought, forest fire, flash/surface flood, river flood, coastal flood, storm surge and saltwater intrusion and severe wind
Bristol	Heat wave, sea level rise, urban flooding, drought, CSOs, windstorm and snow

As can be noted, there are hazards that characterize all the RESCCUE research sites and others that affect just one or some of them. In the following lines, the climate-related variables responsible for all the identified hazards are reported as well as the non-climate related variables .

Rain storm, urban flooding, flash/surface flood, river flood, coastal flood, CSO, snow, hail and drought are all rain climate variables, windstorm is due to wind climate variable, heat wave, sea level rise and extreme hot temperature are related to extreme temperature climate

variable, storm surge is due to wave action climate variable, forest fire is due to wild fire variable, salt water intrusion is due to chemical change (further information can be found in D2.1).

1.3 Sectors and services description for the different sites

This section offers a brief description of the most relevant sectors and services of each research site considered within this project (Lisbon, Barcelona and Bristol). Water Cycle, Power, Mobility and Waste are the sectors mainly treated in this project through detailed analysis of their behaviour during crisis or extreme climate events; however, the services related to each sector are different among sites according to their importance. Table 2 shows a list of services related to their sectors.

Table 2. Sectors and related services

Water Cycle	Power	Mobility	Waste
Urban drainage	Power generation	High speed roads	Waste collection
Water storage	Power distribution	Streets	Waste treatment
Water distribution	Power transportation	Subway	
Water treatment	Electrical mobility network	Railways/Trains	
Water sourcing and transportation	Public lighting and traffic light	Tram	
Wastewater treatment		Bus	
Treated wastewater reuse		Port	
Green infrastructure		Airport	

1.3.1 Lisbon

Some relevant services are related to the **water cycle** of Lisbon. Its sewer system includes combined, separate and partially separate sewers that are characterized by different dimensions, materials and age. Furthermore, the final pipes of the sewer network in Lisbon are affected by the sea level because they are in the lowest part of the City. For this reason, their capacity results quite reduced. Totally, Lisbon sewer system has a length of 1,400 Km.

Water abstraction is mainly from the Castelo do Bode reservoir, whose dam is located in the Tagus river basin and owned by Energias de Portugal (EDP Group), a Portuguese electric utilities company, headquartered in Lisbon. The water treatment is carried out at Asseiceira Water Treatment Plant, while water distribution is conducted by EPAL, which provides any citizen with 650 million litres of drinking water per day. In order to do that, 2,100 Km of water mains, 43 pumping stations, 24 water tanks, 14 service reservoirs and 80 thousand service connections are employed.

In Lisbon, EDP Distribuição manages the power sector. EDP group is the largest producer, distributor and supplier of electricity in Portugal.

The **transport infrastructure** in Lisbon includes 235 bridges and other structures as tunnels and viaducts in the road and rail network. Furthermore, the city has several terminals and

other areas that serve as interface between several ways of transportation, both public and private. Lisbon also has an innovative plan aiming to introduce and increase the use of electrical vehicles. The existing rail network is managed by several organizations: Infrastructures of Portugal S.A., Lisbon's Transports, Lisbon's Metropolitan (ML) and Companhia Carris de Ferro de Lisboa.

Finally, Câmara Municipal de Lisboa (CML) manages the **waste sector** in Lisbon, which handles the collection and the transport of undifferentiated and recyclable waste as well as the pest control and the population of pigeons.

1.3.2 Barcelona

Regarding **water sector** of Barcelona site, drinking water supply is obtained through groundwater sources and the Ter-Llobregat system joint to adequate treatment undertaken in the Sant Joan Despí Drinking Water Treatment Plant (SJD DWTP). Water from the SJD DWTP can be mixed also with drinking water coming from different sources and other large systems like Cardedeu DWTP, Estrella wells and Besòs DWTP. The average water consumption per citizen in Barcelona is nowadays approximately100 litres per day. Therefore, it is one of the lowest water consumptions rates in Europe. Water distribution in Barcelona is conducted thanks to a network of 4,574 Km of pipes, 65 pumping stations and 72 water tanks. Moreover, the network has a telecontrol system available.

The urban drainage system in Barcelona is combined, with the 55% of the sewer system accessible by maintenance personnel. It is characterized by 1,556 Km-length, 15 storm tanks, 44 gates, 15 pumping stations, 41 combined sewer overflows and 31 rainwater sewer overflows.

Concerning wastewater treatment (WWT) in Barcelona, it is carried out through two WWT plants. The first one is known as El Prat de Llobregat WWT, which presents treatment capacity of 420,000 cubic meters per day. The second is the Besòs WWTP and it is the largest in Barcelona, with a capacity of 525,000 cubic meters per day.

Barcelona **power sector** relies on several sub-domains, which are: hydroelectric, wind electricity and solar electricity. The institution responsible for the management of these assets is ENDESA.

The **transportation sector** in Barcelona involves many new areas created in order to incentivize pedestrians and mobility on foot. Journeys on foot and by bicycle present very positive rates (49.29%). The city offers a bicycles public service called "Bicing". Also, public buses, metro and trains are widely used by citizens (50.75%) thanks to their reliability and the high number of stations.

The **telecommunication service** in Barcelona is mainly managed by Telefónica. Its network provides users with telecommunication services through 6,500 buildings and 10,800 other locations as fuse boxes and underground enclosures.

Finally, regarding **waste sector** in Barcelona, waste is collected differently depending on its origin. Household waste collection is conducted by several companies contracted by the City Council and selective collection is incentivized. Commercial waste is collected using the municipal waste system or the Catalan Waste Agency. Furniture and big pieces of junk are

collected freely in assigned days per neighbourhood. There are also many green points to collect polluting waste that cannot be included in any selective collection.

1.3.3 Bristol

Regarding **water cycle** in **Bristol**, water abstraction is made from the River Severn and treated in order to obtain half of current water available. A further 10-15% of water is abstracted from groundwater sources. In cases of demand peaks that exceed the river and groundwater sources, the City uses surface water reservoirs. The Chew Valley Reservoir had been built in order to get more drinking water. This lake is owned by Bristol Water and its capacity is 20 thousand million litres.

Regarding the urban drainage, Bristol is characterized by separate and combined sewer systems. Bristol sewer system is suitable to cope with prolonged rainfall events, but unfortunately the network is not efficient in case of short and intense rainfall because of its limited capacity. Therefore, surcharging and flooding occur in this case. Wessex Water is responsible for managing the sewer network and the associated flood risk from this source in Bristol.

Wastewater treatment is done mainly at Avonmouth, in a big WWT centre that can work with 300 million litres of sewage per day.

Regarding the **power sector,** Bristol has three main sub-domains that are: solar energy, wind energy and biomass. The energy provision is usually conducted by private companies. One of the main electricity providers is Western Power Distribution, which owes 186 electrical substations in the Bristol region. Most of natural gas is provided by British Gas, even though there are many other companies and providers.

About **transportation sector**, Bristol presents many connections and motorways, managed by the Highways Authority. The major roads in Bristol are 18 and the streets are 6,114. Then, the City shows a rail network that connects to all major cities and also a dock widely used for industry and tourism cruises. The airport connects to European and no-European destinations.

In the end, the last one considered in Bristol is **waste sector**. In the City, energy is created from waste thanks to the opening of a Mechanical Biological Treatment plant in Avonmouth, which produces fuel. In the recent periods, furthermore, recycling rate has been 50% because waste collection and waste treatment services have been introduced.

1.4 Known vulnerabilities: Hazards to sectors

After knowing the main sectors and services considered within the RESCCUE project, together with hazards jeopardising the three cities (Lisbon, Barcelona and Bristol), this section describes vulnerabilities of these urban services to the studied hazards. The behaviour of some of the considered services facing extreme climate events for current and future scenarios are analysed comprehensively as well as their impacts.

The affected urban sectors in ***Lisbon*** are power, telecommunications, water cycle, waste, and transport. Although the vulnerabilities of other urban elements such as green infrastructure and urban equipment are analysed too.

In respect of **power sector**, hazards that can provoke failure and disruption are heat wave, sea level rise, urban flooding and windstorm. Jeopardised services are electric transportation and electric distribution because substations, overhead lines and underground cables can be damaged. The main consequences of disruption in this sector may be damage, collapse and interruption of energy supply, but also failures concerning electromechanical and control systems due to water supply cascading effects. Failures in power sector are very likely to provoke also disruption in the urban drainage sector because of failures of pumping and control systems.

For urban **water cycle sector**, jeopardised services are water supply, urban drainage and WWT. Water supply is likely to have a failure in water distribution subsystem, and to the distribution network, because of its vulnerability to drought. If these events occur, the main consequences are insufficient availability and limitation in supply. About urban drainage service, failure affects sewers systems, so sewer networks and pump stations. These critical elements are vulnerable to sea level rise, urban flooding and CSOs.

The main consequences are limited conveyance capacity and high street water level and velocity. There are many cascading effects as road and rail traffic disturbance, flooding of underground infrastructures, solid waste, untreated discharges, pollution of receiving water bodies, high salinity degrading mechanical equipment, and excessive inflow. The last affected service of the urban water cycle is the WWT. Wastewater treatment plants are vulnerable to sea level rise, urban flooding and CSOs. The main damages caused by these events are entry of salty water into the system, potential corrosion of important infrastructures, lower treatment capacity and excessive inflow.

Regarding **waste sector** in Lisbon, the only affected service is cleaning. Critical elements, subjected to damage and disruption, are solid waste containers, which are vulnerable to urban flooding and windstorm. The main direct consequences of these events are damage, displacement and overturn of containers, but there are also several cascading effects on urban drainage like obstruction of components and surface flows.

The **transport sector** is jeopardised by hazards because roadways, rail and metro are vulnerable to sea level rise, urban flooding and windstorm. Main critical elements are roadways, local roads, traffic signals, and rail and metro networks. Flooding and windstorm can provoke disruption of public and private transportation while wind can generate failures of traffic control systems.

On the other hand, **green infrastructures**, mainly trees, are elements which are also jeopardised. They are vulnerable to windstorm, which is often responsible for their collapse. There are many possible cascading effects, among which: obstruction of components, damage to equipment, damage to lines, road and rail traffic disturbance and interruptions.

Lastly, **urban equipment** is another jeopardised element in Lisbon city which should be considered and is vulnerable to urban flooding and windstorm. Main consequences are expressed mostly in terms of cascading effects, like damage of urban drainage due to obstruction of components, damages to equipment and lines, road and rail traffic interruptions.

In ***Barcelona*** city, vulnerable urban sectors are power, telecommunications, urban water cycle, waste, mobility and other elements such as green infrastructure. About **power sector**, vulnerable services are power generation, power transmission and power distribution. In

particular, critical elements are: large power plants, distributed power plants, high-voltage overhead lines, high-voltage buried cables, conventional electric substations, underground power substations, compacted substations, gas isolated substations, substations, medium voltage overhead grid, medium-voltage buried grid and transformation centres. These elements are vulnerable to rainstorm, severe wind, forest fire, flash/surface flood, river flood, coastal flood, storm surge and saltwater intrusion. For Barcelona site, energy service is the most critical because the other urban services rely on it, therefore a disruption in energy supply may affect telecommunications, urban water cycle, waste collection, waste treatment and transportation systems.

About urban **water cycle sector**, vulnerable sectors are water supply, urban drainage and wastewater treatment. The affected subsystems are water abstraction, water treatment and storage, water distribution and sewers system. In particular, critical elements are: catchment wells, drinking water treatment plants, desalination plants, drinking water network, water storage tanks, groundwater network, Sustainable Urban Drainage systems (SUDS), sewer network, pumping stations, interceptors, gates, weirs, waste water treatment plant, saline intrusion barrier network and saline intrusion barrier wells. They are vulnerable to rainstorm, severe wind, drought, forest fire, flash/surface flood, river flood, coastal flood and saltwater intrusion.

Waste sector is also vulnerable in Barcelona. Affected subsystems are solid urban waste (SUW) collection, treatment and cleaning. Critical elements are treatment plants, cleaning centres/vehicle storage, pneumatic waste collection plants. They are vulnerable to rainstorm, severe wind, forest fire, flash/surface flood, river flood, coastal flood and storm surge. A failure in this sector may have heavy consequences on citizens' health, economic activity and image of the City. Furthermore, a significant cascading effect of a disruption of waste service is the failure of the drainage system because of obstructions caused by the waste.

Regarding **mobility sector**, it is vulnerable to rainstorm, severe wind, forest fire, flash/surface flood, river flood, coastal flood and storm surge. Mobility services subjected to the previous vulnerabilities are mainly roadways, rail, metro, infrastructure for river and sea transportation. In particular, critical elements are structuring basic network, secondary network, local basic network, surface and underground railway network, surface and underground railway stations. The main consequences of failure of mobility services are given by disorder in mobility flows, critical influence in the City functionality. The most affected services among urban sectors would be waste collection and cleaning services, but also the power sector may be subjected to major damages because the energy supply depends on fuel and therefore a failure in its transportation provokes alterations o failures in the energy sector as well.

The last urban element jeopardized by climate change hazards in Barcelona is represented by green infrastructures, which are vulnerable to: severe wind, heat wave, extreme hot weather drought, forest fire, flash/surface flood, river flood, coastal flood, storm surge and salt water intrusion.

In ***Bristol***, the main vulnerable sectors, analysed within RESCCUE project, are power, urban water cycle, waste and transport. About the **power sector**, just power transmission and power distribution sectors are vulnerable, while power generation is not. Elements as substations, overhead lines and underground cables are vulnerable to windstorm and snow. Therefore,

the main direct consequences are damages, collapse and interruption of energy supply. Among cascading effects, water supply, urban drainage, wastewater treatment, traffic control and telecommunication services may be subjected to disruption.

Water supply, urban drainage and wastewater treatment are the vulnerable sectors of the urban **water cycle sector**. Critical elements are distribution networks, pumping stations, water treatment plants and sewer networks, which are vulnerable to: heat wave, sea level rise, urban flooding, drought and CSOs. Main consequences of these events are insufficient availability, limitation in supply, treatments performance reduction, limited conveyance capacity, high street water level and velocity, water quality deterioration, excessive inflow. Among the main cascading effects, there are: energy supply failure, mechanical failure, telecontrol failure, communication disruption and road traffic disturbance.

Regarding **waste sector**, the only vulnerable elements have been identified in the Solid Urban Waste Collection (SUW) subsystem. In particular, the vulnerable element is represented by waste vehicles. They are vulnerable to urban flooding, which can provoke damage and road closures. Also cascading effects can occur on urban drainage, like obstruction of components and surface flows.

The last vulnerable sector identified in Bristol is the **transport** one, in particular roadways and rail networks. Critical elements are roads, traffic signals and railway tracks (both superficial and underground elements). They are vulnerable to sea level rise, urban flooding, windstorm and snow. Main consequences are interruption of public and private transportation, failures of traffic control systems and damage to underground infrastructures.

2 Multisectoral resilience strategies framework

Within the RESCCUE project the concept of resilience adopted is aligned with the one proposed by the United Nations International Strategy for Disaster Reduction (UNISDIR, 2009): **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**. RESCCUE project understands the city (Bristol, Barcelona and Lisbon) as a system and its essential basic structures and functions are the different urban sectors and services as well as their interactions.

In order to achieve this "ability", consequences of different climate impacts must be understood first, and proper adaptation strategies must be consequently proposed. The specific adaptation strategies can be formed by one or more general adaptation measures to cope with today and future's climate impacts on urban areas. Adaptation strategies are understood as sets of measures that aim to tackle one concrete issue related to climate change adaptation. Measures contain specific actions targeted to address a problem within the scope of the strategy they belong to. It means that a measure can be displayed in more than one strategy, because it tackles more than one problem (e.g., green areas could support flooding control and air pollution strategies).

On the other hand, the difference between **mitigation and adaptation** should be noted also, seeing that although both are complementary and essential aspects of climate protection, these are not addressed in the same manner. Whilst the first, within the framework of climate change, is mainly focused on the reduction of greenhouse gas emissions (GHGe), the second, in the case of cities, means the establishment of measures to decrease the vulnerability and increase the resilience facing those not desirable effects (Ventayol, 2014).

Addressing mitigation and adaptation jointly can maximize the benefits of actions taken and stakeholders must ensure that any action taken in pursuit of one goal does not undermine progress toward the other. On a global scale, successful early mitigation efforts may reduce future harms and related adaptation costs, but some climate change impacts are already unavoidable in some parts of the world and will require adaptation (ICLEI, 2010). In RESCCUE project only adaptation strategies are considered.

The criteria proposed here to select adaptation strategies are an **effectiveness indicator,** the **co-benefits**, the strategies **estimated cost**, and an indicator related to the damages and risks reduction of the adaptation actions.

1. **Effectiveness indicator**

2. **Co-benefits**

3. **Strategies estimated cost**

4. **Damages and risk reduction**

An **effectiveness indicator** helps to assess the success of the resources used in achieving the objective of each measure (Guerreo-Hidalga et al, 2020). It is important to select one that is valid across measures of different characteristics, and that requires information that is available. An effectiveness indicator could be the reduction of downtime of urban services after an extreme weather event—recovery time reduction. For example, a 1D/2D hydrodynamic model could provide an estimate of a flooding residence time. When a set of measures is modelled (i.e. adaptation scenario), a new flood residence time can be estimated and compared with the non-adapted situation. This variation of recovery time could be used as an effectiveness indicator, which indicates how effective a specific set of measures is.

The concept of recovery time is not a new one within the resilience framework, since it can be found in some works employed as a resilience indicator. Bruneau *et al.* (2003) for instance, introduced the concept of resilience triangle (Figure 2), which indicates a significant and a sudden decrease of functionality due to an extreme event at a certain time instant, followed by a gradual recovery of functionality, until it is fully functional after a time increment (recovery time).

- Often estimated through some combination of simplified modelling, past experience, and/or expert opinion.
- Recovery times for services supported by the built environment have a direct impact on the economic vitality and social well-being of the community.

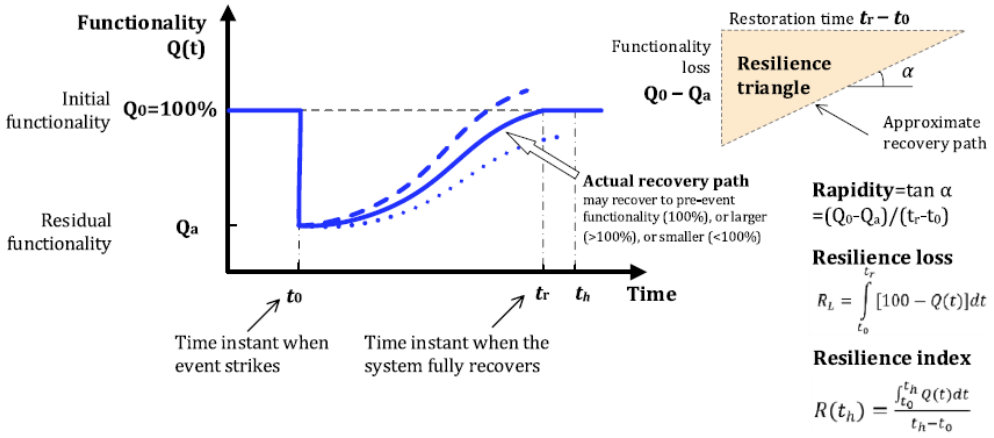

Figure 2. Resilience triangle and resilience index (source: Sun *et al.* (2018))

The engineering laboratory of the National Institute of Standards and Technology (NIST) (U.S. Department of Commerce) (Kwasinski *et al.*, 2017) states that the recovery times is one of the primary types of resilience metrics.

Another example would be the San Francisco Planning and Urban Research Association (SPUR), that in order to establish metrics for earthquake-related resilience in San Francisco, developed its own methodology based on the recovery time as a resilience index. Therefore, the use of this variable within this framework is not a new approach, although here more variables are considered jointly (i.e. co-benefits and strategies estimated cost) to assess the adaptation strategies effectiveness.

Other relevant criterion for adaptation measures are the possible **co-benefits** that may occur when implementing a specific measure. Economic, social, and environmental co-benefits are

those benefits, or positive effects, generated in parallel to the main objective of the policy, understood as the specific climate change adaptation goal (Floater et al., 2016). The quantification and monetization of co-benefits is surrounded by uncertainty; thus, co-benefits were accounted for using a scoring system evaluated by experts from diverse disciplines in each case study. This method also involves uncertainty, but the method is less time-consuming and considers local knowledge.

The evidence suggests that citizens are more likely to act on climate change, or more likely to support governments that act on climate change, if the wider co-benefits of those actions are emphasised (Bain *et al.* 2015). At the city level, the potential of co-benefits is particularly great as citizens can often witness the results of policy actions more directly on their daily lives (Floater *et al.*, 2016). Several names for the same definition can be found in literature, such as win-win situations, life-cycle benefits, triple-win scenarios, consequential benefits, ancillary benefits, mutual benefits, consequential life cycle impacts, etc.

Ürge-Vorsatz *et al*. (2014) states that co-benefits should be included in decision-support frameworks. In this sense, a list of co-benefits, grouped in three different types (i.e. economic, social and environmental), has been proposed herein (Table 3). These co-benefits are based on those proposed in the report "Co-benefits of urban climate action: A framework for cities", developed by C40 Cities climate leadership group and LSECities (Floater *et al.*, 2016). Therefore, within the required information for each measure, the importance of each listed co-benefit will be considered by establishing a weight from zero (no effect) to ten (totally beneficial). Somehow, it must be considered as a matrix of weights of co-benefits related to each adaptation measure.

Table 3. Types of co-benefits proposed to be associated to the different adaptation measures

Economic	Social	Environmental
• Cost savings	• Reduced mortality impacts	• Improved air quality
• Reduced energy losses	• Reduced health impacts	• Improved water quantity
• Job creation	• Reduced mortality from diseases	• Reduced aquifer depletion
• Possible reduction in prices	• Enhanced public amenity	• Reduced water pollution
• Increased labour productivity	• Reduced impacts on vulnerable groups	• Reduced land contamination
• Increased economic production	• Reduced number of householders, businesses forced from homes, places of work	• Improved biodiversity and ecosystems
• Increased property values	• Social inclusion	• Maintained and increased green space
		• Reduced environmental impacts through associated awareness
		• Increased biodiversity and ecosystem services
		• Effective/uninterrupted water collection and security
		• Erosion control

Another important reason, if not the critical one, for a decision maker for implement adaptation options is their cost, not only the initial investment but also the cost burden resulting from their maintenance. Therefore, their **estimated cost** is considered a key

parameter to decision making, which will be related to each proposed adaptation strategy as an important variable in order to make decisions to select them.

Finally, **a climate risks reduction** indicator of the adaptation effectiveness can be understood as a percentage of high-risk area reduced. The higher the number of risks assessed, the more comprehensive the prioritization of adaptation measures would be. Risks, such as the stability of pedestrians or vehicles exposed to water flows and damages caused to properties and vehicles are some of the ones assessed within the framework of RESCCUE.

Considering the criteria described before, the proposed prioritization methodology must offer a flexible approach, able to adapt to different urban contexts. The balance between expertise, resources requirements, accuracy, and replicability of results is an important consideration during the design process. The capacity of the methodology to allow for different levels of detail must be also considered, due to the diverse data availability, which normally limits the assessment potential. Meeting these requirements must be made possible by developing a method that followed the principles of Multi-criteria Assessment (MCA), in the sense that it (i) gives relevance to stakeholder decisions; (ii) uses normalized quantitative and qualitative indicators through a scoring system; (iii) is able to rank options with different goals; and (iv) offers a multi-phase analysis approach.

The framework of the proposed methodology to prioritise adaptation measures is formed by phases that are composed by combinations of assessment methods, ordered from coarser to more detailed assessments. The first stage includes a CEA and co-benefits scoring assessment, whereas the following phase is based on more detailed assessments—risks reduction assessment and CBA. In addition, the methodology proposes several variables to rank results that help decision-makers to downselect the most suitable measures for their specific policy goals. An introductory diagram of the methodology is available in Figure 3, which is further explained in D5.2.

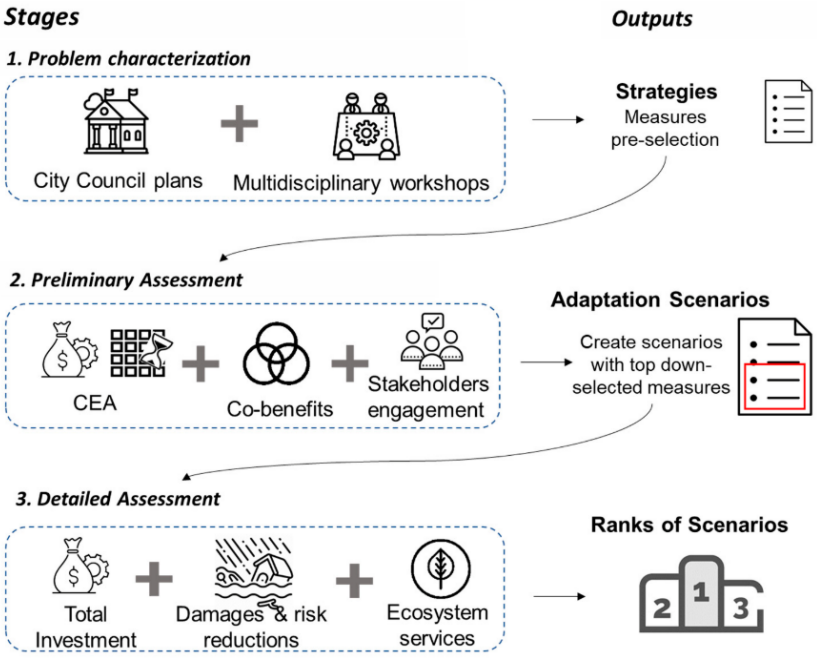

Figure 3. Selection of adaptation measures framework

It must be noted that while adaptation measures are proposed to be prioritised in a preliminary assessment, adaptation scenarios (i.e. set of adaptation measures) are ranked in the subsequent detailed assessment. It is frequent that decision makers are interested in implementing the most efficient set of measures (i.e. adaptation scenario).

3 Web-based platform

A budgetary relocation, because of the Opticits' termination, was approved in the last Grant Agreement Amendment to develop a new web-based platform to support decision makers in an effective and efficient selection of climate adaptation measures. This new platform, in comparison with the initial development described in D5.1, integrates new functionalities and presents a better performance and a more intuitive design for users to have a greater experience. The initial aim in this WP5 was the development of a regular database to gather climate adaptation measures based on a comprehensive state-of-the-art review and the knowledge of the consortium in climate adaptation for different urban utilities. Both, a greater ambitious and an extra budgetary boost allocated to this new task, have led to a more comprehensive tool which may contribute to the prioritization of adaptation options process at the municipal level. The methodology to prioritize adaptation measures that is behind this platform was described in D5.2, and is more extensively explained and applied to Barcelona and Bristol in a new article published in the open access journal Sustainability, entitled as "Methodology to Prioritize Climate Adaptation Measures in Urban Areas. Barcelona and Bristol Case Studies" (Guerrero-Hidalga *et al.*, 2020). As a summary, the methodology proposed follows a multi-phase structure to progressively narrow down the list of potential measures. It begins using less resource-intensive techniques, to finally focus on the in-depth analysis on a narrower selection of measures. It involves evaluation of risks, costs, and welfare impacts, with strong focus on stakeholders' participation through the entire process. The methodology is adaptable to different contexts and objectives and has been tested in Barcelona and Bristol.

In order to create a measures' database, it was necessary to receive contributions from all the partners involved in this task who have knowledge on specific sectors, and hence on adaptation measures related to these sectors. The required information to properly characterize adaptation measures has been proposed based on the conducted literature review and the suggestions of the city councils (Barcelona, Lisbon and Bristol) according to their needs.

Once the diagnosis of current situation within a city is done, which will lead to an initial pre-selection of strategies, decision makers can use this web-based platform. The use of this decision support application aims at supporting the strategies effectiveness study to make the **selection of measures** to be implemented.

To develop all needed functionalities for the platform it was decided to conduct a tailored development by considering the PHP Laravel's framework. Currently, Laravel is the most widely employed PHP framework globally, and its performance in recent years makes it a benchmark when it comes to web development.

The database used was Postgresql, a free and open-source relational database management system emphasizing extensibility and SQL compliance. It is extremely robust and quick, and

allows having JSON form fields. This web-based platform is divided into two applications: A user front-end and a management back-end.

3.1 Front end App

In the public front-end App users may gain access to the platform and conduct their own assessments. This App is broken down into two parts: public (users) and private (admin) (Figure 4).

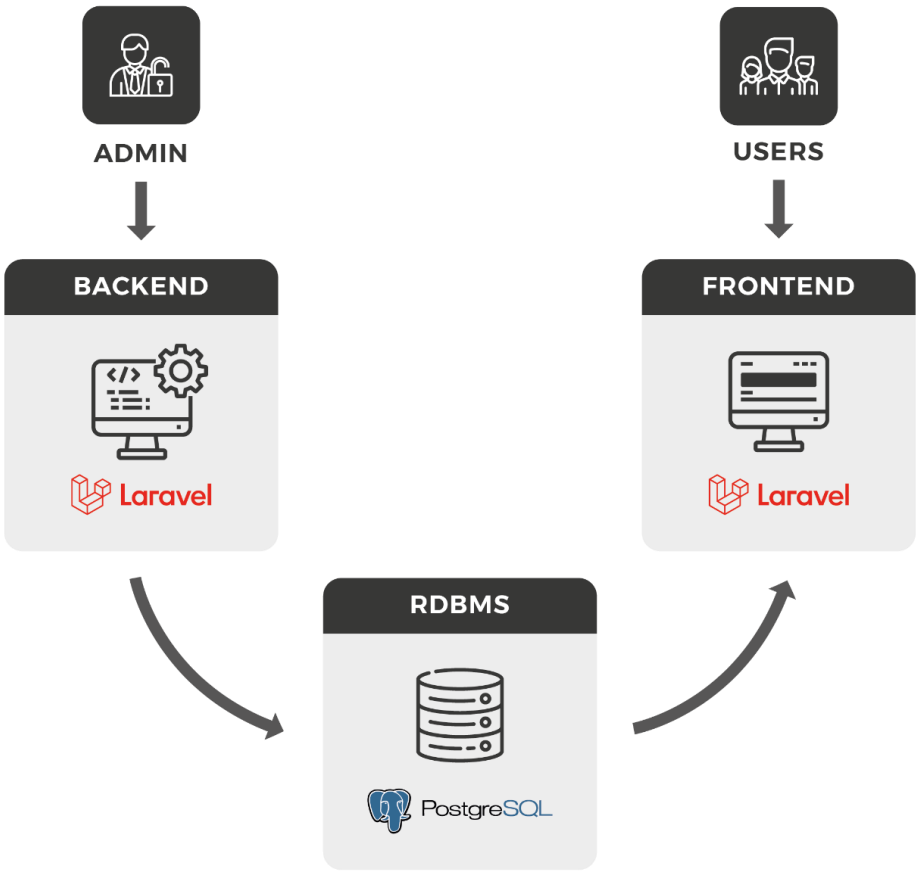

Figure 4. Scheme of the adaptation strategies platform

The first one, publicly available, is formed by the Home, FAQs and measures database sections:

- **Home page**: The main characteristics of the Project RESCCUE are described in this section.
- **FAQs**: This is a users' guidance section, where some frequent questions are tried to be answered in a clear and concise manner.
- **Measures**: A list of 182 adaptation measures are publicly available without any register required. A filter per several fields is provided for the user to easily find their adequate measures (Figure 5). The filters available are climate hazard, key benefits, measure type, spatial scale, urban sector and target.

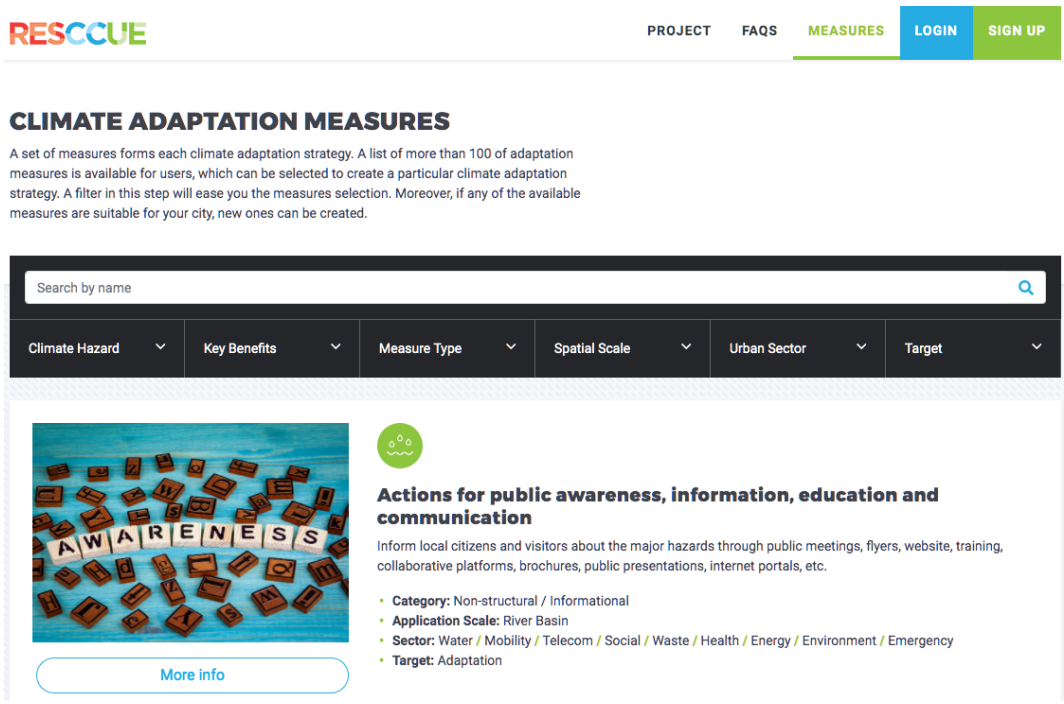

Figure 5. Front-end: display of the measures section

Other functionalities are offered in the front-end App for registered users. The sign up is optional (Figure 6 & Figure 7) and only a validated email is required to gain access to all the platform functionalities:

- **User-defined adaptation measures**: Users, apart from having access to the public measures database, can create their own measures in case none of the ones provided fit well for their purposes. Through a measures form, users can provide all characteristics to define a measure.
- **Strategies**: Users can create strategies (Figure 9), formed by a set of adaptation measures. These measures may be selected from both the public database and the private list of measures created by the user. During the strategy creation process the user will be requested to provide all the details about how the measure will be implemented, its costs and the effectiveness indicators.
- **Ranking**: Once all information is provided by the user, the App provides a rank of all the measures that form the strategy (Figure 10). The methodology and calculations behind this step are comprehensively describes in D5.2 and in the article published in the open access journal Sustainability, entitled as “Methodology to Prioritize Climate Adaptation Measures in Urban Areas. Barcelona and Bristol Case Studies”. The results provided in columns tables and radar charts can be downloaded to facilitate the presentation of results to users.
- **Adaptation Scenarios**: The entire set of adaptation measures that form a strategy may not be all implemented at a time, thus subsets of measures, named as adaptation scenarios, may be proposed by the users and a prioritization of them will be provided by the App. Additional downloadable tables and graphs summarizing the results are provided.

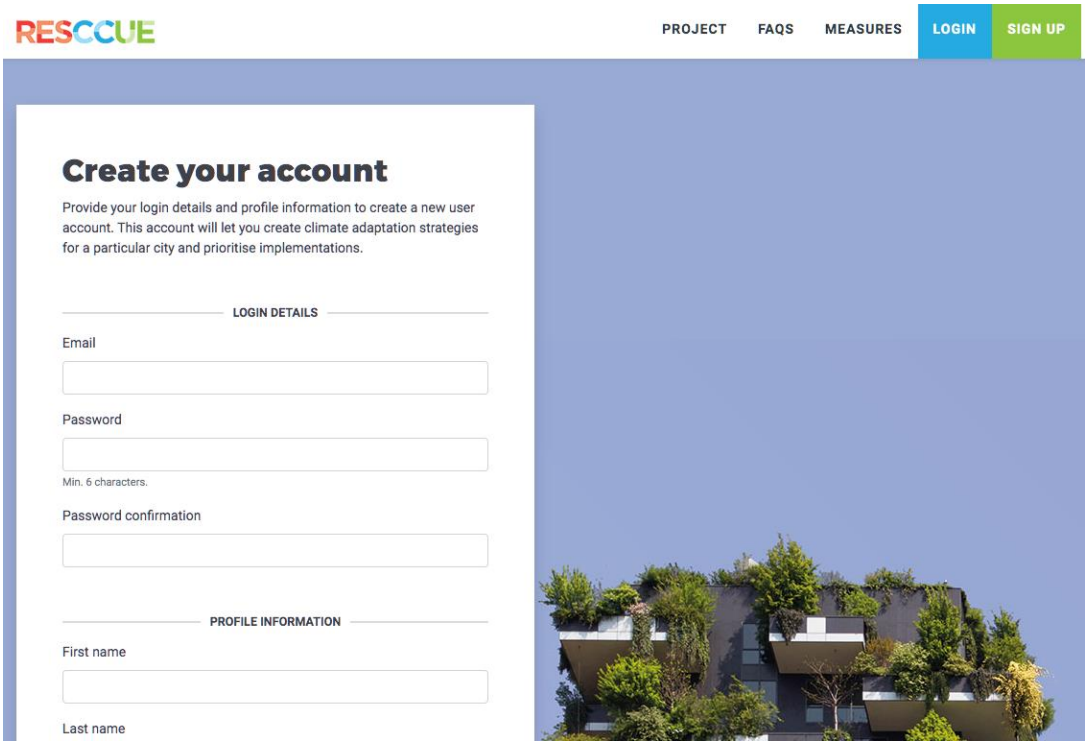

Figure 6. Sign up platform section display

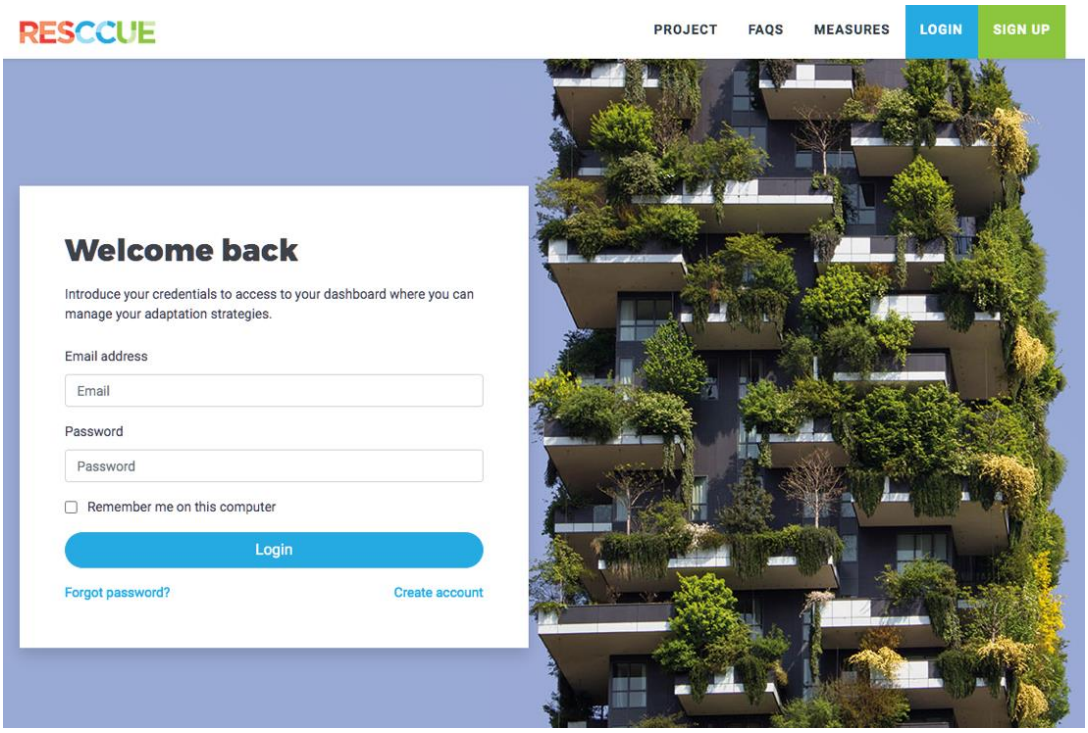

Figure 7. Login platform section display

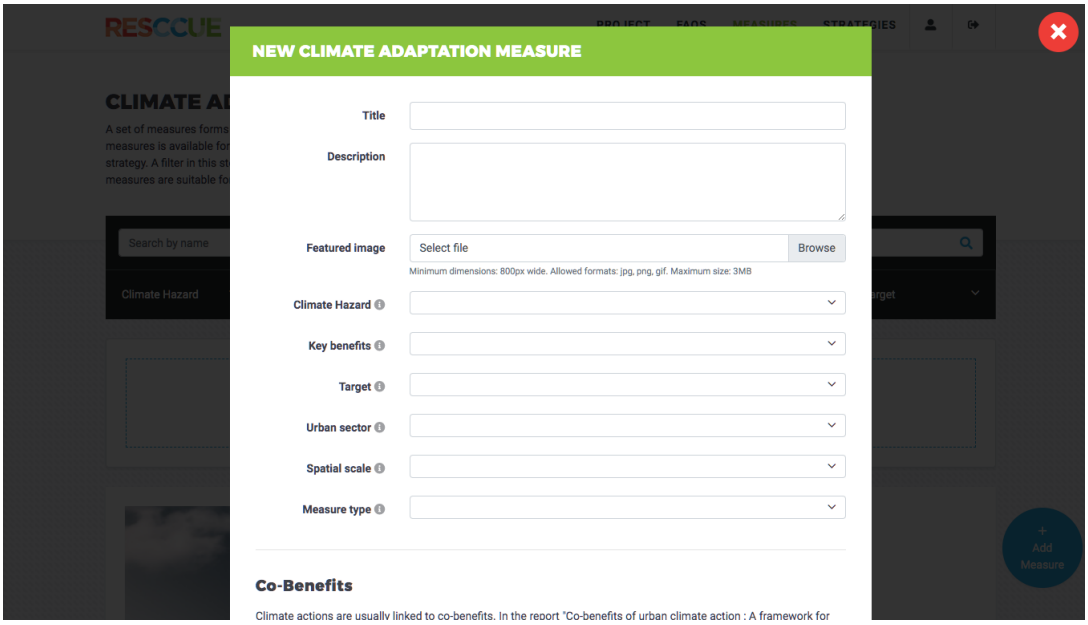

Figure 8. Creation of an adaptation measure display

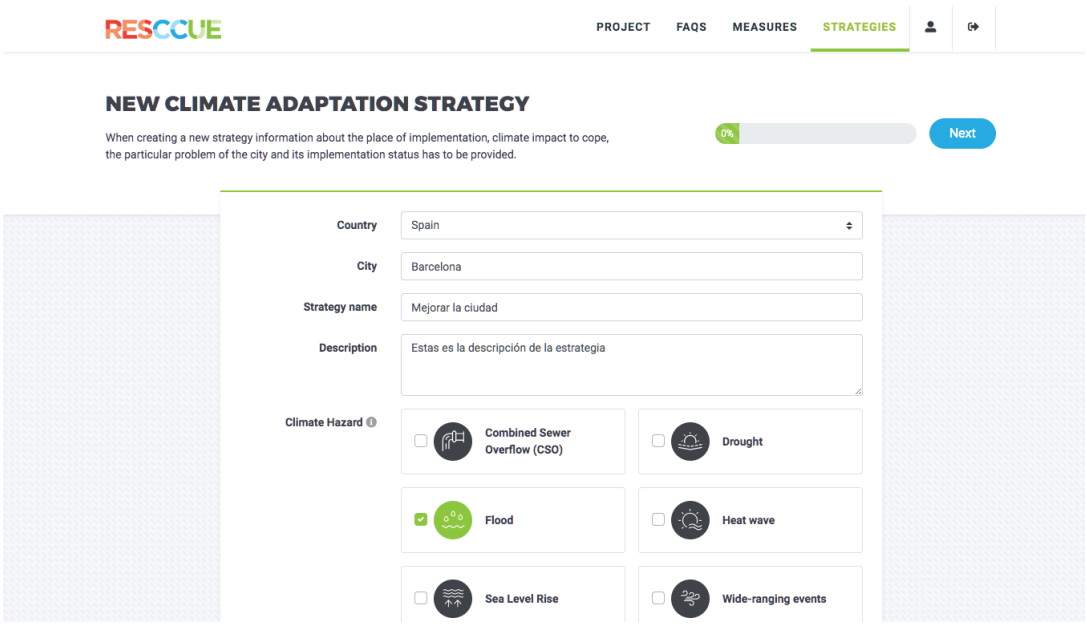

Figure 9. Creation of an adaptation strategy display

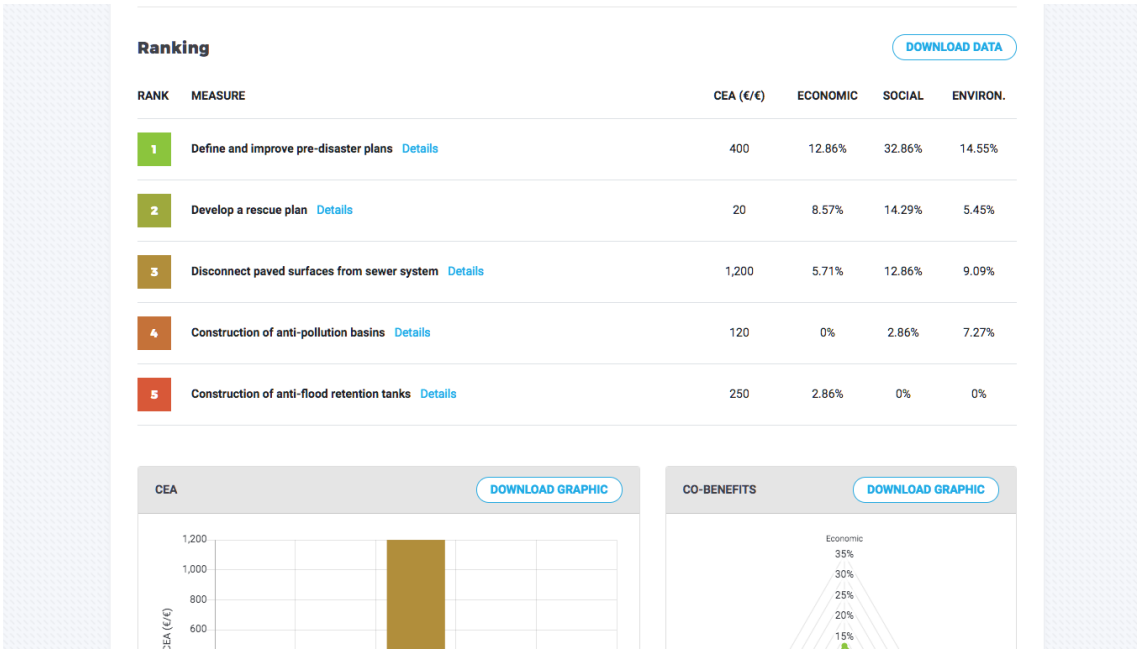

Figure 10. Measures ranking display

3.2 Back end App

The back end is the App that allows the administrator to manage user profiles, measures and strategies. Its access is only gained through a user and password access (Figure 11) and it is stored in a private URL that is only known by the management team project.

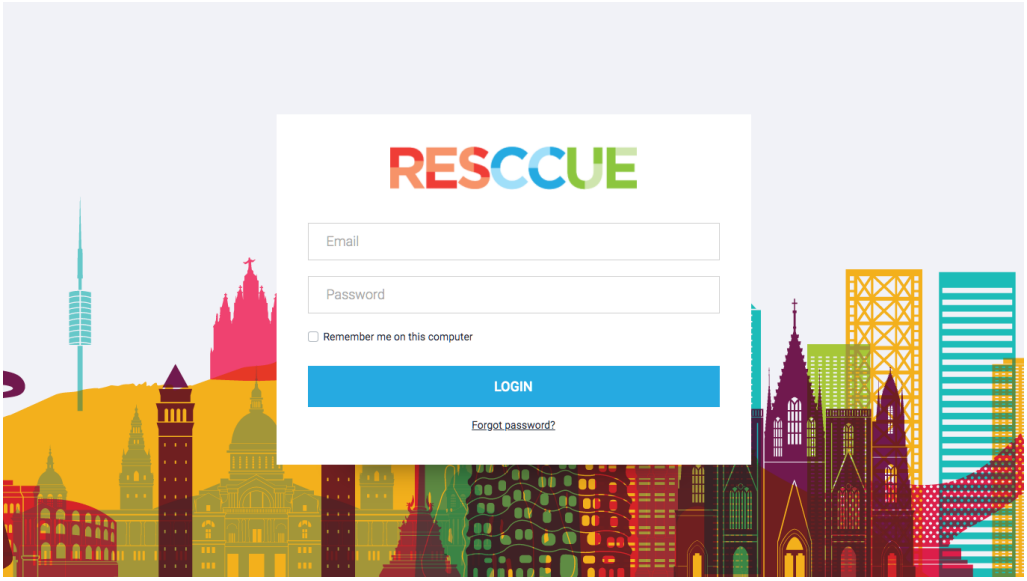

Figure 11. Back end app login display

Through the back-end App, measures included in the database can be looked up, created, modified and removed. Currently 182 measures are available within the database to be selected by the user when creating a strategy (Figure 12 & Figure 13). Besides, looking up and editing of strategies created by registered users is also possible (Figure 14 & Figure 15).

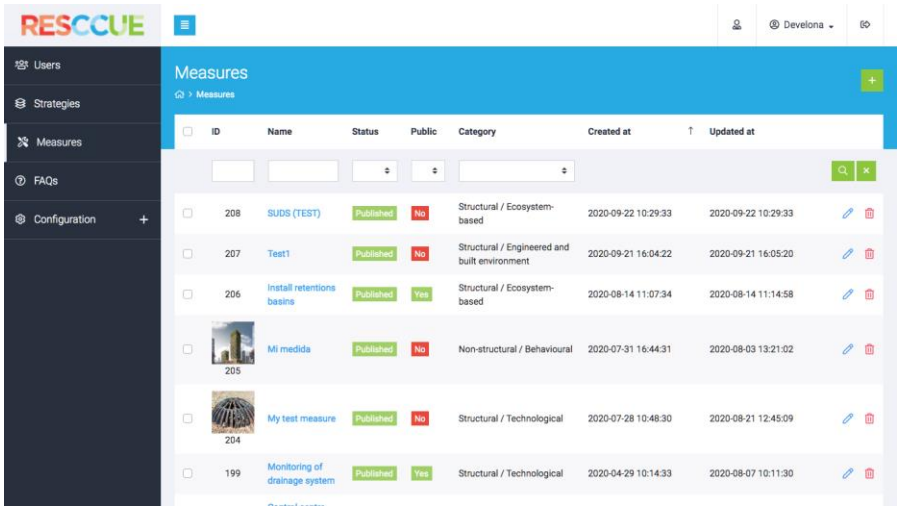

Figure 12. List of measures display in the back-end App

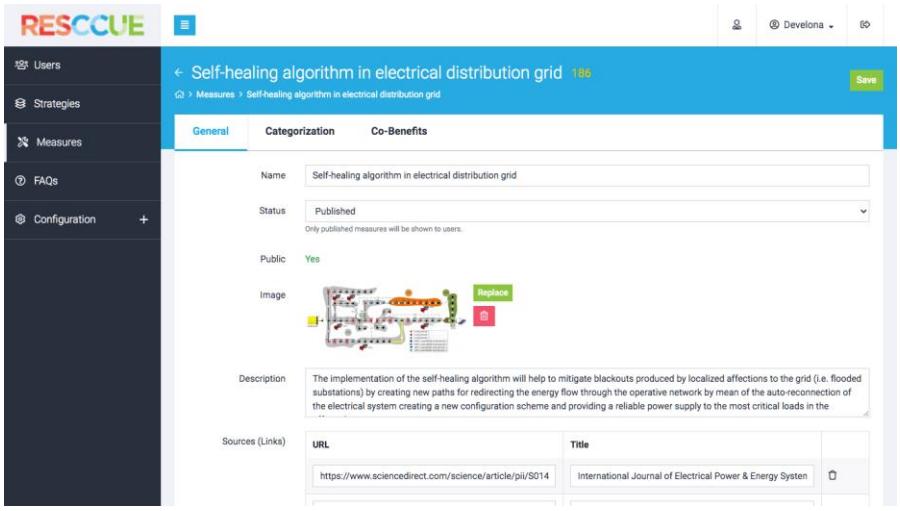

Figure 13. Measure's editing display in the back-end

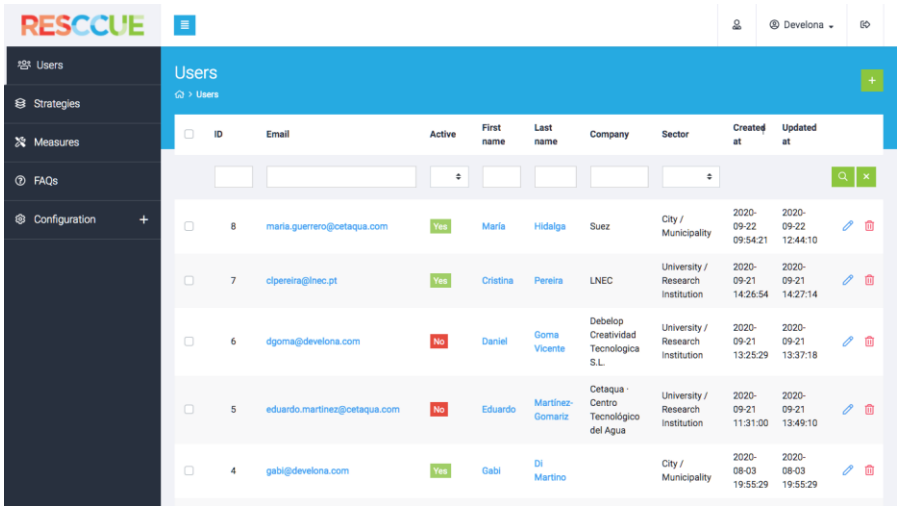

Figure 14. Registered users' editing display in the back-end App

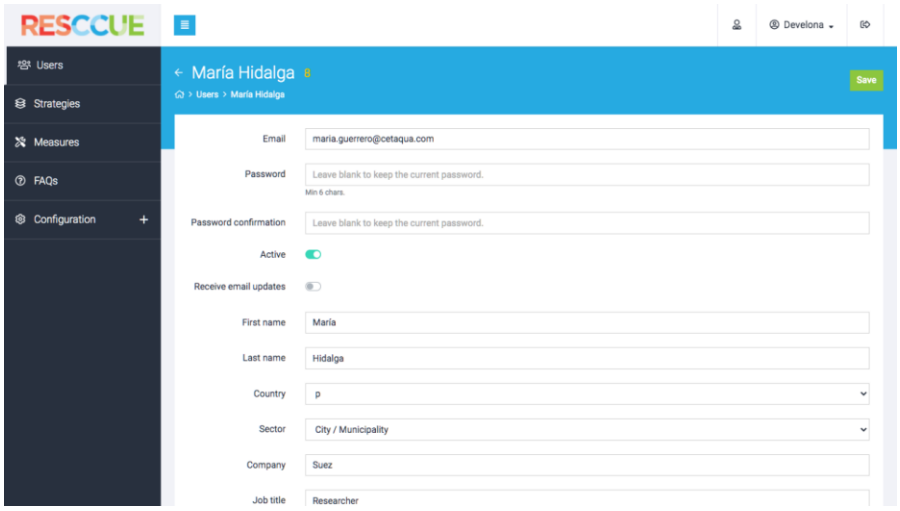

Figure 15. Registered user's details in an editable display in the back-end App

4 Conclusions

In order to bridge the cities' gaps (increasing their resilience), thereby improving the way to face the hazards and the related potential risks to urban services, adaptation measures will have to be implemented. The present framework has given first a general context about RESCCUE project by describing the considered hazards, sectors and services, together with the already known vulnerabilities (i.e. hazards to sectors) for the different sites. Afterwards, some relevant criteria are proposed here to make decisions for the adaptation measures selection.

Furthermore, a procedure to prove the strategies effectiveness has been proposed. Based on a literature review and the shared partners' knowledge, and taking advantage of the city councils' contributions, a database of adaptation measures has been performed. This database has been included in a decision support application (web-based platform) in order to facilitate the strategies creation and provide support on prioritising adaptation options.

REFERENCES

Bain et al. (2015). Co-benefits of Addressing Climate Change can Motivate Action Around the World.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A., & von Winterfeldt, D. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra, 19(4), 733–752.

Floater G., Heeckt C., Ulterino M., Mackie L., Rode P., Bhardwaj A., Carvalho M., Gill D., Bailey T. and Huxley R., (2016). Co-benefits of urban climate action: A framework for cities. C40 Cities report. London (United Kingdom).

Guerrero-Hidalga, M., Martínez-Gomariz, E., Evans, B., Webber, J., Termes-Rifé, M., Russo, B., & Locatelli, L. (2020). Methodology to Prioritize Climate Adaptation Measures in Urban Areas. Barcelona and Bristol Case Studies. Sustainability 2020, Vol. 12, Page 4807, 12(12), 4807. https://doi.org/10.3390/SU12124807

ICLEI (2011), Financing the Resilient City. A Demand Driven Approach to Development, Disaster Risk Reduction and Climate Adaptation – An ICLEI White Paper. International Council for Local Environmental Initiatives (ICLEI), Bonn.

Kwasinski A., Trainor J., Francis R., Chen C., Lavelle F.M. (2017) Further Development of a Conceptual Framework for Assessing Resilience at the Community Scale (NIST GCR 17-013). National Institute of Standards and Technology (NIST). U.S. Department of Commerce. 88p (online: https://doi.org/10.6028/NIST.GCR.17-013)

Manca A.R., Benczur P., Giovannini E. 2017. Building a scientific narrative towards a more resilient EU society, Part 1: a conceptual framework, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-67660-4, EUR 28548 EN, doi:10.2760/635528.

Sun W., Bocchini P., and Davison B.D. (2018). Resilience metrics and measurement methods for transportation infrastructure: the state of the art, Sustainable and Resilient Infrastructure. 32p.

United Nations Office for Disaster Risk Reduction (UNISDR), (2009). Terminology on disaster risk reduction, UNISDR, Geneva. Available at: http://www.unisdr.org/we/inform/terminology

Ürge-Vorsatz, D., Herrero, S. T., Dubash, N. K., & Lecocq, F. (2014). Measuring the co-benefits of climate change mitigation. Annual Review of Environment and Resources, 39, 549-582.

Ventanyol, I. (2014). Barcelona, ciutat resilient al canvi climàtic (Barcelona, a resilient city to climate change). Ajuntament de Barcelona, España.

ANNEX. Summary of projects related to climate adaptation measures for specific sectors

In this annex, a table to summarize the main information of the different reviewed project is offered in order to ease the access to further information if required.

Table 4. Summary of reviewed projects

Project	Sector	State	Coordinator/Responsible/Author	Link
Collaborative Research on Flood Resilience in Urban areas (CORFU) (2010-2014)	Water cycle	Finished	The University of Exeter (United Kingdom)	http://www.corfu7.eu/
PREPARED "Enabling Change" (2010-2014)	Water cycle	Finished	KWR WATER B.V. (The Netherlands)	http://www.prepared-fp7.eu/
Preparing for Extreme And Rare events in coastaL regions (PEARL) (2014-2018)	Water cycle	Finished	UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION –UNESCO (France)	http://www.pearl-fp7.eu/
Climate RESilient cities and Infrastructures (RESIN) (2015-2018)	Water cycle	Finished	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO (The Netherlands)	http://www.resin-cities.eu/home/
Bringing INnovation to onGOing water management – A better future under climate change (BINGO) (2015-2019)	Water cycle	Finished	LABORATORIO NACIONAL DE ENGENHARIA CIVIL (Portugal)	http://www.projectbingo.eu/
PLAtform for Climate Adaptation and Risk reDuction (PLACARD) (2015-2020)	Water cycle	Finished	FCIENCIAS.ID - ASSOCIACAO PARA A INVESTIGACAO E DESENVOLVIMENTO DE CIENCIAS (Portugal)	http://www.placard-network.eu/
BRIdges the GAp for Innovations in Disaster resilience (BRIGAID) (2016-2020)	Water cycle	Finished	TECHNISCHE UNIVERSITEIT DELFT (The Netherlands)	http://brigaid.eu/
FLOOD-CBA (2013-2015)	Water cycle	Finished	Sigma Consultants Ltd (Greece)	http://www.floodcba.eu/
Balancing energy production and consumption in energy efficient smart neighbourhoods (e-balance) (2013-2017)	Power	Finished	IHP GMBH - INNOVATIONS FOR HIGH PERFORMANCE (Germany)	http://ebalance-project.eu/
Improving the Robustness of urban Electricity Networks (IRENE) (2014-2017)	Power	Finished	AIT Austrian Institute of Technology	http://ireneproject.eu/

Project	Sector	State	Coordinator/Responsible/Author	Link
Realising European ReSiliencE for CritIcaL INfraStructure (RESILENS) (2015-2018)	Power	Finished	FUTURE ANALYTICS CONSULTING LIMITED (Ireland)	http://resilens.eu/
Smart Mature Resilience for more resilient cities in Europe (SMR) (2015-2018)	Power	Finished	TECNUN. University of Navarra (Spain)	http://smr-project.eu/home/
PORLisboa: Improved Public Lighting	Power	Finished	Camara Municial de Lisboa	https://goo.gl/T1SgxN
PPEC Lisboa: LED in Traffic Lights	Power	Finished	Lisboa E-Nova and EMEL Agencia de energia e ambiente de Lisboa	https://goo.gl/88QpTE
Lisbon: Energy Efficient use in Public Lightning	Power	Finished	Lisboa E-Nova and EMEL Agencia de energia e ambiente de Lisboa	http://lisboaenova.org/index.php
Risk Analysis of Infrastructure Networks in response to extreme weather (RAIN) (2014-2017)	Mobility	Finished	Trinity College Dublin	http://rain-project.eu/
Climate Change and Everyday Mobility (CLIMAMOB) (2015-2018)	Mobility	Finished	The University of Oxford's Transport Studies Unit (TSU)	https://goo.gl/Cv2AAt
Providing Transport Services Resilient to Extreme Weather and Climate Change (2015)	Mobility	Finished	Transport for London (TfL)	https://goo.gl/nfa9xE
Adaptation of transport to climate change in Europe, Challenges and options across transport modes and stakeholders (2014)	Mobility	Finished	European Environment Agency	https://goo.gl/QLRN1P
Mobi-E: Electric Mobility in Lisbon	Mobility	Finished	Lisboa E-Nova and EMEL (Lisbon Mobility and Parking Municipal Company)	https://goo.gl/YcUyCt
Guide to Climate Change Adaptation in Cities. The World Bank Group report (2011)	Waste	Finished	The International Bank for Reconstruction and Development/ The World Bank	https://goo.gl/zRDQUr
Increasing the climate resilience of waste infrastructure. Adapting to Climate Change, DEFRA report (2012)	Waste	Finished	AEA Technology	https://goo.gl/ihUncQ
Climate Change Resilient Development (CCRD) project. U.S. Agency for International Development technical report (USAID) (2012)	Waste	Finished	Global Climate Change (GCC) Office	http://www.ccrdproject.com/

Project	Sector	State	Coordinator/Responsible/Author	Link
Waste management options and climate change (2001)	Waste	Finished	AEA Technology	https://goo.gl/dCdygM
Food Surplus and Its Climate Burdens (2016)	Waste	Finished	Ceren Hiç, Prajal Pradhan, Diego Rybski, and Jürgen P. Kropp Potsdam Institute for Climate Impact Research Department of Geo- and Environmental Sciences	https://goo.gl/2xVN48
Adapting Waste and Recycling Collection Systems to the Changing Climate (2011)	Waste	Finished	Waste and Resources Action Programme (WRAP)	https://goo.gl/sKjEHa
LIFE PAYT – Tool to Reduce Waste in South Europe (2016-2019)	Waste	Finished	Polytechnic Institute of Coimbra	http://www.life-payt.eu/pt/
UrBAN-WASTE (2016-2019)	Waste	Finished	GOBIERNO DE CANARIAS	http://www.urban-waste.eu/
Climate Risks Study for Telecommunications and Data Center Services (2014)	Telecom	Finished	The US General Services Administration (GSA)	https://goo.gl/up5fem
Climate Change: the Contribution of Telecommunications (2009)	Telecom	Finished	Ewan SUTHERLAND Research Associate, LINK Centre	https://goo.gl/CKJSTL
Climate Change Adaptation (2010)	Telecom	Finished	Ofcom	https://goo.gl/S3mfZ2