Ref. Ares(2015)4759229 - 01/11/2015

RESIN
SUPPORTING DECISION – MAKING FOR RESILIENT CITIES

RESIN Publication

Library structure online. Adaptation options database model

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Deliverable No.	3.1
Work Package	3
Dissemination Level	Public
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Date	30/10/2015
File Name	D3.1_ Adaptation options database model_Tecnalia_2015-10-30
Status	Ready for submission
Revision	
Reviewed by (if applicable)	Jeremy Carter, Vera Rovers, Peter Bosch, Marta Olazabal, Ibon Galarraga, Anil Mankandya, Hypatia Nassopoulos, Eva Pauditsova

This document has been prepared in the framework of the European project RESIN – Climate Resilient Cities and Infrastructures. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 653522.

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1. Introduction

The RESIN project will develop standardised approaches to help city administrators, the operators of urban infrastructure networks, and related stakeholders to develop their **adaptation strategies** and ensure that their decisions strengthen the resilience of the whole city. These will be comprehensive by dealing with all elements of the urban system: critical infrastructures, built-up spaces and public spaces, and will cover impact-and-vulnerability assessment and **selection of adaptation options**. RESIN will develop a decision support system to support decision makers in following a standardised path towards the choice of appropriate and effective **adaptation options** into strategies tailored to the particular circumstances of a specific city. RESIN will explore the possibilities and prepare the materials **to include adaptation** in European standardisation processes, in key European directives and existing guidelines for integration of the climate change to these directives [1].

RESIN will build on the concept of adaptive policy making which involves repeated steps: (1) Understanding the impacts (2) vulnerabilities and risks (3) selecting the most appropriate interventions (4) choosing the best implementation strategy (5) implementing options and (6) monitoring and learning. There is a scarcity of well-structured operational and standardised tools to identify and implement the best performing, efficient and effective adaptation options for a particular context. This means that there is a knowledge gap on the increased understanding of the applicability and (cost) effectiveness of adaptation options.

RESIN project contribution (relating to adaptation options) at a glance consist on:

- *Common frameworks, a city typology for adaptation (WP1, task 1.3), decision making tools based on standardised assessments of impact, vulnerability and risk, and the applicability and effectiveness of adaptation options (WP2, WP3 and WP6).*
- *A catalogue of adaptation options that are based on standardised conventions for reporting on costs and effectiveness (WP3, especially task 3.1).*
- *A methodology for assessing adaptation costs, benefits, risks and opportunities within the urban setting (WP3, task 3.2).*

Therefore, one of the results of RESIN project will be the catalogue of the adaptation options which it is expected be very useful tool for many European initiatives on climate change adaptation and disaster risk reduction[2].

[1] The results of the RESIN project (especially catalogue of the adaptation options) can also support the integration of the climate change issues into the directives on environmental impact assessment and strategic environmental assessment, directive on water, directive on habitats and can support their better practical implementation. The catalogue of the adaptation options can be used also for updating the EC Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment and Strategic Environmental Assessment: http://ec.europa.eu/environment/eia/pdf/EIA%20Guidance.pdf and http://ec.europa.eu/environment/eia/pdf/SEA%20Guidance.pdf

[2] For example Mayors Adapt Initiative34, the UNISDR Making Cities Resilient campaign35, C40 and Connecting Delta Cities36 and national and international city networks (such as the UK “core cities group”, the Dutch “G4” or the Union of Towns and Cities in Slovakia.

The catalogue of adaptation options is devoted:

- *to a wide range of adaptation options for urban environments and their critical infrastructures and*
- *to develop standardised information on their applicability and effectiveness.*

Standardisation in this respect will imply:

- *Proposing standard ways of communicating the cost and benefits (performance) for the most used adaptation options. Practically, RESIN will deliver a catalogue of urban adaptation options (technical options as well as ecological and behavioural/institutional ones) with comparable information on costs, benefits and effectiveness for various climatic and urban conditions. The catalogue will be based on the city typology and will be structured in accordance with existing approaches in disaster risk management (prevention, preparedness, response and recovery).*
- *Proposing standard metrics for assessing the performance of similar adaptation options, applied under similar conditions (e.g. within similar urban contexts). This includes costs and benefits for such options under diverse local conditions, as well as proposing standard units for expressing those costs and benefits.*

In summary the catalogue will have the following roles:

- *Provide the reference documentation to any decision support tool to be developed (by RESIN and also by others in Europe).*
- *Provision of data which is used by other models/calculations. As an example, the users could extract effectiveness per unit information from the library and use this information to calculate/show in more detail the effectiveness.*
- *To do quick selection (through filtering and searching): advanced sorting of options based on multiple criteria.*
- *Going beyond the advanced sorting, the library will provide the information for the prioritization of the options. The criteria holding the library will be the base information to prioritize options through the standardized methods.*
- *Moreover, the prioritization and the implementation information hosted in the library will be part of the information used for the formulation of the adaptation approach (definition of the pathway could be an example).*

Therefore, it is a strong link between the catalogue and the decision support system (WP6), as the catalogue will support the Decision Support Tool. To support the demands of adaptive policy making, RESIN will bring together the elements of the decision support system in a practical e-guide: the RESIN Suite of Decision Support Tools for Urban Climate Change Adaptation Planning. This e-guide will include tools for actor/stakeholder analysis; impact, vulnerability and risk assessment; adaptation options and risk reduction; cost-benefit analyses; and guidelines for decision-making under uncertainty.

And last but not least, our aim is for the project results to be integrated in the Climate-Adapt platform http://climate-adapt.eea.europa.eu/, after project completion. Climate-Adapt represents a one-stop shop for European adaptation and features a special section focused on tools.

2. Explanation of the aim of this report

This report is intended to presents the criteria for evaluating climate adaptation options. Evaluation criteria of climate adaptation are based on the existing adaptation databases, platforms and libraries, scientific reports and policy documents for climate adaptation. For this end, this study reviews existing evaluation dimensions, concepts, frameworks and criteria. The aim is to define the dimensions and criteria needed for climate adaptation evaluation, to do an exhaustive description and check with some adaptation options their usefulness, suitability, possibility to characterize and potentiality (to be used in the prioritization processes).

More specifically, this study will develop a library/catalog of standard(-ized) adaptation options. It will (1) collect a large sample of adaptation options that have designed or already been implemented at the city level across Europe and worldwide. Then this work will also (2) put forward standard values for characterizing the adaptation options in terms of costs and benefits linked to specific conditions of implementation. Finally, (3) all the information will be organized in the form a library/catalog of adaptation options that will allow benchmarking and classifying such options in a number of relevant dimensions. The first step would therefore consist on the database design and completion.

The library/catalog will be based on a relational model that will include all the key analytical dimensions to be considered for a complete characterization of the adaptation options assessed in RESIN. The database will be designed and implemented following open-source standard tools and protocols for database management (PostgreSQL, MySQL...). This will be done in coordination with WP6, making the database fully compatible and/or implementable into the Decision Support System developed in the RESIN project.

The database of adaptation options will underpin the activities performed within all the other WP of the RESIN project by (1) allowing partners to access the database in all phases of implementation; and (2) by enabling partners to upload information to the database. A data entry form will be designed for this purpose. The database will also be made accessible by city managers, practitioners, and the general public upon registration on the project website. The RESIN project will also ensure that the catalog of adaptation options will remain accessible even after the project implementation phase.

The review process has considered on going and finished projects, researches and initiatives (published reports and papers), existing climate platforms and web sites. The reviewed material covers different levels of adaptation and different sectors.

3. Functionality of the database

Because the database will be accessible to a variety of agents with different necessities, it will be necessary to clarify firstly who will be these possible agents (project partners, politicians, city managers, network managers, researchers, citizens...) and what specific permits will be given to any of them to access to the contents of the database. That means the type and quantity of provided data will depend on the type of user and its assigned role into the database. Every possible user of the RESIN database should be assigned to one of the user profiles predefined into the database, who will have or not, at the same time, some roles, permits, privileges, etc. to read or even write data. For example, it is evident that a project partner or a city manager will have more privileges than public in general, allowing not only to select, but also to insert, delete or update records of some editable tables containing adaptation options. Besides, controlling who can modify contents of the database will ensure a better quality of data to be stored.

The database should be accessible through a graphical user interface, preferably from a Web browser, to provide an easier way of getting information from anywhere, avoiding so additional installations of software in the client side. At the same time, the user interface should be customized and closely related to the users already defined in the database. A user with more privileges, as a partner of the Consortium, for example, will have an interface with more data available than a citizen. The appearance of the interface and the different data to be shown in any case will be controlled once the user has registered and logged in the Web platform. If someone enters the platform without logging, as an anonymous user, the provided data will be the more basic ones, without the possibility, of course, of modifying any data.

In a first stage, the database should have two main capacities. On one hand, it will allow advanced users recording specific adaptation options. Any of the characteristics of these options to be inserted into the database will have its corresponding textbox, listbox or any other graphical control included as part of the user interface. Those fields of the editable tables will be accessible to users with privileges of entering data. On the other hand, the database will also provide the existing information to any user through the customized interface. It would be even possible that some specific data would be only available for some users and not for others. It will be possible to do both simple searches, looking for options based on a unique criteria (hazard, scale, type, receptor,…), and more advanced searches, considering at the same time several criteria, concatenated with logical operators such a as “AND”, “OR, etc.

Respect to the type of content stored in the database, data will be stored following a relational model where tables, and relationships among them, make up the core group of objects. There will be some tables, not editable by the majority of users, that will store data to be used into the web application. For example, only a user with administrative privileges (superuser) should modify a table which includes, for instance, the climatic bioregion where one adaptation option has been tested or implemented. On the other hand, there will also be some editable tables that could be modified by more people, those advanced users that have permits to add or delete adaptation options into the database. It will have to be considered later if new tables arise in case that the standardization and prioritization are based on the generation of local scenarios with a limited number of options to be analyzed.

Besides tables, other objects will probably be incorporated into the database structure during the development of the project. Views or indexes to control user access to data or to increase speed in getting information, if necessary, are among the possible additional objects to be considered by developers and the database administrator. Special concern will be given in a following stage to how to implement the processes of harmonization/standardization of data and options prioritization as part of the database or the Decision support System to be developed in WP6, that might imply the inclusion of new database objects such as, for example, rules, functions or triggers for transforming raw data into useful information.

4. The database structure

The database is organized in 4 domains: general information, organisation, effectiveness and cost-efficiency. Then every domain has several dimensions and sub-dimensions:

1. GENERAL INFORMATION
   - Title
   - General description
   - Image/photo
   - Climate threat
   - Type
   - Geography
   - Scale
   - Sector
   - Technology Readiness
   - Urban typology

2. ORGANISATION
   - Responsible party
   - Primary beneficiary group
   - Feasibility
   - Technical barriers and requirements: spatial and subsurface depth requirements, geomorphologic conditions, micro-scale climatic conditions
   - Non-technical barriers and requirements: human resources, social and cultural requirements, regulatory landscape, investments costs, financing
   - Maintenance
   - Acceptability

- Easy to use
- Easy to implement
- Monitoring

3. EFFECTIVENESS
    - Main element of concern
    - Impact magnitude reduction: heat, flood and wind storm
    - Vulnerability reduction: exposure, sensitivity and adaptive capacity
    - Impact radius
    - Robustness
    - Flexibility
    - Time horizon, implementing time and effective life time
    - Side-effect
    - Uncertainty

4. COST-EFFICIENCY
    - Investment cost
    - Benefit
    - The relationship between cost and benefit
    - Co-benefit
    - Uncertainty
    - Combinability

4.1 General information (Table 1)

This dimension aims to give the important basic information of each adaptation option. Most of the criteria defined into this section will serve for filtering and searching. This dimension, together with the organisational, will characterize the adaptation options. The characterization consists on a general description of the adaptation options, indicating objective(s), scale, sector and technology readiness level, among others. Characterization is considered a prerequisite towards the subsequent selection and prioritization of the most suitable measure to be implemented.

4.1.1. Title

Name of the adaptation option: the title will define briefly the adaptation option.

4.1.2. General description

The adaptation option will be described: aim, functioning, etc.

4.1.3. Image/photo

Visualisation of the option.

4.1.4. Climate threat

It refers the climate hazard(s) addressed by the option.

4.1.5. Type of options. [1]

This section describes the dimension of the options, classifying in different types. This categorization aims to take into account the diversity of adaptation options for different sectors and stakeholders. Some options cut across several categories. Furthermore, some adaptation options are interrelated.

– Structural/Physical: Engineering and built environment (Grey), Technological, Ecosystem based (Green-Blue) and services oriented [1]

  Structural/physical category highlights adaptation options that are discrete, with clear outputs and outcomes that are well defined in scope, space, and time. They include structural and engineering options; the application of discrete technologies; the use of ecosystems and their services to serve adaptation needs; and the delivery of specific services at the national, regional, and local levels.

  - Engineering and Built Environment: Engineering, and the multidisciplinary teams engineers work with (architects, planners, legal experts, etc.), are often at the forefront of delivering adaptation technologies and strategies. Most engineering options are expert driven, capital-intensive, large-scale, and highly complex. While many of the engineering options —including management of storm and waste water flow (both inland and coastal), flood levees, seawalls, upgrading existing infrastructures to improve wind and flooding resilience, beach nourishment, and retrofitting buildings —are extensions and improvements of existing practices, plans, and structures; some newer projects are now integrating changed climate risk into the initial design. Engineered adaptation options typically have two general limitations. First, they often must cope with uncertainties associated with projecting climate impacts arising from assumptions about future weather, population growth, and human behaviour. Second, the longevity and cost of engineered infrastructure affect the feasibility at the outset. They also are subject to consequences that were not anticipated. Many have promoted a “phased capacity expansion” strategy, which allows engineered projects to undertake design modification as conditions or knowledge change and facilitate incremental project construction to ease the burden of upfront financing.
  - Technological Options: Recent advances in technology and information are being combined with engineering structural adaptation options in various applications. In the food and agriculture sector, a suite of adaptation options have been developed and applied to reduce the adverse impacts of climate change on production. Technologies range from more efficient irrigation and fertilization methods, plant breeding for greater drought tolerance, and adjusting planting based on projected yields to transfers of traditional technologies such as floating gardens. Technology options for climate change adaptation include both “hard” and “soft” technologies, and not only new technologies but also locally made appropriate technology. Centralized high-technology systems can increase efficiency under normal conditions, but also risk cascading malfunctions in emergencies. With the rapid diffusion of Information and Communication Technologies (ICT) such as mobile phones and the Internet, the unprecedented speed at which information is produced and shared is posing a new set of possibilities for communication. ICT provides opportunities for top-down dissemination of relevant information such as

weather forecasts, hazard warnings, market information, information sharing, and advisory services. It can also generate essential information through bottom-up processes such as “crowd sourcing” of useful information such as local flood levels, disease outbreaks, and the management of disaster responses.

- Ecosystem-Based Adaptation: Ecosystem-based adaptation (EBA) —which is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change —is becoming an integral approach to adaptation. Working with nature’s capacity and pursing ecological options, such as coastal and wetland maintenance and restoration, to absorb or control the impact of climate change in urban and rural areas can be efficient and effective means of adapting. The use of mangroves and salt marshes as a buffer against damage to coastal communities and infrastructure has been well researched and found to be effective both physically and financially in appropriate locations. They can also provide biodiversity co-benefits, support fish nurseries, and have carbon sequestration value. Other EBA activities include integrative adaptive forest management and the use of agroecosystems in farming systems, ecotourism activities, land and water protection and management, and direct species management. Green infrastructure (including the use of green roofs, porous pavements, and urban parks) can improve storm water management and reduce flood risk in cities, and can moderate the heat-island effect, as well as having co-benefits for mitigation. Ecosystem-based approaches are often more difficult to implement and assess as they usually require cooperation across institutions, sectors, and communities, and their benefits are also spread across a similarly wide set of stakeholders. One of the major barriers to EBA is the lack of comparable standards and methodologies applied to engineering approaches, thus demonstrating the need for more dialog between engineering and ecological communities.
- Service Options: Service provision consists of a diverse range of specific and measurable activities. For instance, one measure to support the most vulnerable populations is social safety nets. Programs designed to provide support via food programs, micro-finance, or insurance at times of extreme events can provide an important bridge for vulnerable populations. Public health services also are important for tackling projected increases of disease incidences spurred on by climate change. Governments at all levels are often also responsible for maintaining adequate access to services that are projected to be further stressed due to climate change. Frequently cited options in this domain include, among others, clearing drainage systems to prevent floods, diversifying water supply services to account for changing water supplies, and maintaining open public spaces dedicated for disaster recovery and other emergency purposes. At the local level, infrastructure associated with the provision of basic services, such as water, sanitation, solid waste disposal, power, storm water and roadway management, and public transportation are integral to increasing adaptive capacity. Transport links enable households to take part in trade, for example, to access agricultural markets although supply chains can be vulnerable to climate disruption. Housing services are particularly critical because new patterns in temperature and precipitation will alter the habitability and stability of residences while increased frequency and intensity of natural disasters will place settlements and homes on both stable and unstable land at greater risk.

– Social: Educational, Informational and Behavioural

There are various adaptation options that target the specific vulnerability of disadvantaged groups, including targeting vulnerability reduction and social inequities. Community-based adaptation refers to the generation and implementation of locally driven adaptation strategies, operating on a learning-by-doing, bottom-up, empowerment paradigm that cuts across sectors and technological, social, and institutional processes. Social protection schemes include public and private initiatives that transfer income or assets to the poor, protect against livelihood risks, and raise the social status and rights of those who are marginalized. Awareness raising, extension, outreach, community meetings, and other educational programs are important for disseminating knowledge about adaptation options as for helping to build social capital that is critical for social resilience. Education can be seen as a public good that promotes dialog and networks, and therefore allows the development of resilience at both the level of the individual learner and at the level of socio-ecological systems. Research partnerships and networks can facilitate knowledge-sharing and awareness raising at all levels from small groups of individuals to large institutions. Informational strategies, such a as early warning systems (tone alert radio, emergency alert system, presentations, and briefings,...), are critical to ensuring awareness of natural hazards and to promoting timely response, including evacuation. Heat wave and health warning systems can be designed to prevent negative health impacts, by predicting possible health outcomes, identifying triggers, and communicating prevention responses. Climate services initially emerged as an expansion of the tasks provided by weather services, and can act as "knowledge brokers" that establish a dialog between science and the public, to facilitate decision support. ICT is facilitating rapid dissemination of information. However, low-tech options such as brochures, public service announcements, and direct contact with local residents also are important to fostering awareness and response especially where access to ICT is limited or expensive. Behavioural options are among the suite of options that are integral to advancing climate adaptation.

– Institutional: Economic, Laws and regulations, Government policies and programs

Institutional options range from economic instruments such as taxes, subsidies, and insurance arrangements to social policies and regulations. Laws, regulations, and planning options such as protected areas, building codes, and re-zoning are also institutional options that can improve the safety of hazard-prone communities by designating land use to support resilience. A number of funding and financial issues are linked to institutions. At the international level, agreements and donors have a critical role to play in promoting and supporting the allocation and flow of financial resources. Effective governance is important for efficient operations of institutions. In general, governance rests on the promotion of democratic and participatory principles as well as on ensuring access to information, knowledge, and networks.

We need to understand Governance in its broader sense which includes basic functions of local, regional self-government, state government, public committee in executive, NGOs, experts, private sector, cooperation etc. It is important to assess the adaptive capacity of local governmental units, institutions and policies through applying qualitative and quantitative approaches and subsequently to give insight to their linkages and networking in order to process climate change related adaptation activities at national, regional and local levels.

4.1.6. Geography: geographical Region. [2][3]

It describes for which climatic region is the adaptation option. Climate change regions (not only climate regions) are regions with similar climate change characteristics and derive from a cluster analysis of 8 climate change variables: change in annual mean temperature, summer days, frost days, snow cover days, winter precipitation, summer precipitation, heavy rainfall days and annual mean evaporation. Climate changes are calculated on the basis of a comparison of 1961-1990 and 2071-2100 climate projections from the CCLM model for the IPCC SRES A1B scenario. In the end five clusters (Southern-Central Europe, Northern Europe, Northern-Central Europe, Mediterranean region and Northern-western Europe) were identified, each exhibiting distinct regional climate change profiles.

4.1.7. Scale [4]

It refers to any of the spatial scales on which it is possible to implement adaptation options, ranging from the national to the building or infrastructure itself or parts of it.

Scale of implementation for efficient risk reduction at the city level can be:

- At the urban scale, components and parameters for architectural and spatial quality include infrastructure, urban form, proximity to facilities and functions, access to green areas, building typology and morphology, transition between different urban areas and city boundaries.
- At the building scale, examples include views, isolation and contact, internal and external arrangements, transition between public and private domains, and perceived density.

4.1.8. Sector

Sector(s) for which the option can provide a solution: Building, Water supply, Wastewater treatment, Communications (ICT), Health, primary sector, Critical Infrastructure (transport: road, rail, air, Inland waterways, ocean and short-sea shipping and ports; energy: electricity, oil, gas; green infrastructure) (Council Directive 2008/114/EC)[3],.

According to the Commission Staff Working Document "Adapting infrastructure to climate change", the term "infrastructure" usually refers to physical assets in a wider range of policy areas, including communications, emergency services, energy, finance, food, government, health, education, civil protection, transport or water. Buildings, from private households to schools or industrial installations, are the most common type of infrastructure and the basis for human settlement. In addition, network infrastructure is crucial for the functioning of

[3] Council Directive 2008/114/EC, EC SWD(2013) 137 and 155

today's economy and society, notably infrastructure for energy (e.g. grids, power stations, and pipelines), transport (fixed assets such as roads, railways or airports), ICT (e.g. data cables) and water (e.g. acces to clean water, water supply pipelines, reservoirs, waste water treatment facilities). They are sets of interconnected networks which facilitate the production and distribution of goods and economic services, and form the basis for the provision of basic social services. Overall, there are many interdependencies between the infrastructure sectors and failure in one area can quickly lead to cascade failure. Energy, water, ICT and transport infrastructure are also often co-located (e.g. power cables laid below roads and beside communications cables, adjacent to water and gas mains and above sewers), especially in urban areas. Extreme weather events could conceivably affect (or disrupt) all of these infrastructure assets simultaneously.

The Communication from the EC "Green Infrastructure (GI) - Enhancing Europe's Natural Capital" defines Green Infrastructure as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.

4.1.9. Technology Readiness Level

It refers the technology maturity of the option. Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – Basic principles observed
- TRL 2 – Technology concept formulated
- TRL 3 – Experimental proof of concept
- TRL 4 – Technology validated in lab
- TRL 5 – Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – System prototype demonstration in operational environment
- TRL 8 - System complete and qualified
- TRL 9 – Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

4.1.10. Urban typology

To be included later (the city typologies defined into the RESIN project will be included into this criterion)

4.2 Organisation (Table 7)

The aim of this dimension is to contribute information related to the organisation or implementation of the adaptation option. This description would address the technical feasibility of options, requeriments for their implementation, the responsibilities for implementation and financing, the cultural acceptability of the technology involved, etc. [5] This information will be usefull for the implementation strategy.

4.2.1 Responsible party [6] [7]

Stakeholder responsible for implementation- It relates to the governance and institutional needs:

- National government
- Regional administration
- Municipality
- Company
- Household/individual
- Water board/water catchment management organization

4.2.2 Primary beneficiary Group [8]

It refers to the social impact of the measure and it can be exclusive (attention placed to vulnerable group or groups so only one section of the population) or inclusive (all citizens): potential diversity strands (age, disability/special needs, ethnicity -related to language as a barrier-), demographic dependency (children and youth), senior citizens (elderly), disabled/ special needs (physical, mental or sensory disabilities), immigrants, single-parent families, households with one member, unemployed, beneficiaries of minimum incomes (insertion), households with less than half the national average income, poor people / homeless, people with (or without) studies (primary, secondary, tertiary studies), people with health problems.

4.2.3 Feasibility

To what extent is the option sensitive to barriers preventing the implementation of the option (e.g. technical, political, climatic, spatial):

- Highly sensitive
- Moderately sensitive
- Slightly sensitive
- Not sensitive/no barriers known

4.2.4 Requirements [9]

This criterion gives an idea of the requirement for the implementation of the measure. The required information will be yes or no in the following requirements: spatial requirements (gives an idea of the land requirement for the implementation of the measure: depending on the land cover characteristics or the density of an urban area, it is more complex or less to implement a measure with high or low space requirement); subsurface depth requirements (it refers to the subsurface depth required for the measured to be effective: those could be express as requirements or as barriers for the implementation of technical options); geomorphologic conditions: slope of the terrain (sloping area, flat area on high ground with deeper groundwater levels, flat area on low ground with shallow groundwater levels), soil type (sand, peat, clay, bed rock); micro-scale climatic conditions: solar radiation, temperature, precipitation pattern; human resources (qualified human resources required in terms the expected expertise and profile, during the implementation)[8][9][10]

4.2.5 Maintenance

To what extent is maintenance required to maintain the effectiveness of the option (once this has been implemented. i.e. how onerous is the maintenance requirement…). Degree of intensity: high, moderate, low.

4.2.6 Acceptability

Is the option accepted by the public/is it politically and socially acceptable?

– Stakeholder/political acceptance: widely accepted, largely accepted, little acceptance, unaccepted
– Social/citizen acceptance: widely accepted, largely accepted, little acceptance, unaccepted.

4.2.7 Monitoring

It refers to monitoring of adaptation measures implementation. The objective here is to quantify the outcome of an adaptation option on a system's sensitivity or adaptive capacity, and thus its vulnerability. It is possible to distinguish between adaptation level to be monitored and the time interval:

– Project level (every 3-5 years)
– Adaptation program or strategy (every 5-10 years)

4.3 Effectiveness (from to Table 6)

The effectiveness is the hazard and the vulnerability components reduction (i.e. magnitude reduction) due to the adaptation options. Due to the multi-sectoral nature of adaptation, one adaptation option can contribute to different dimensions of adaptive management approach (see Figure 1) such as: reducing the magnitude of the impact (m^3 of rainfall caught by a green infrastructure), reducing the exposure (reduction of the number of people exposed to flooding, reducing the sensitivity (number of buildings with improved isolation), improving the adaptative capacity (rate of healthy centers), etc. As a consequence the effectiveness of each dimension is measured with different metrics.

Apart from this, with the aim of contribute to the lack of metrics in the adaptation field the follwing information will be included into the effectiveness fields, such as i) the local conditions (the effectiveness of adaptation options is highly dependent on the local conditions of the place where the measure is applied, ii) the baseline scenario, iii) the time expression of the results and iv) the location where the results are achieved.

And last but not least, there are more criteria linked with the concept of effectiveness (but they are not directly) that this dimension will cover: the impact radius, robustness, flexibility, the time (time horizon, implementing time and effective life time), side-effects and uncertainty.

4.3.1 Main impact area

Which element of risk does the option influence most: Hazard, Exposure, Sensitivity, Adaptive capacity.

4.3.2 Impact magnitude reduction

– Heat reduction

The aim is indicating the effectiveness of the measures regarding heat impacts.
There are different **variables to measure the heat-reduction options**; depending on the elements under the stress reduction is given:

- Regarding the heat-reduction, normally air temperature is needed for the simulations. For the thermal comfort variables, other meteorological variables are needed such as relative humidity, wind speed, cloud coverage, etc.
- For humans, thermal comfort indexes are normally used such as (Physiological Equivalent Temperature: PET, Universal Thermal Climate Index: UTCI, Equivalent Temperature: ET; Predicted Mean Vote: PMV, among others). The usefulness of each indicator depends on the circumstances to be measured. However, PET and PMV seems to be the more used. The effectiveness of certain green options is calculated with the air temperature.

Once the variable is defined, there **are other relevant parameters** related to the meteorological information, baseline or reference situation, the location, and the time expressions of the results, that should be specified in order to make the results useful for comparison.

For example, considering a greening measure that consists on replacing a paved surface by a greening area two trees in a park. It is not the same to express the effectiveness:

With no additional information: *The greening measure achieves a reduction of PET in 2ºC.*
With additional information: *Comparing with the paved surface, the greening measure achieves a reduction of PET in 2 ºC in the morning (average from 9 a.m to 12. a.m) and 1 ºC on the afternoon (average from 15.00 to 19.00) in a bench located below the tree on a typical summer day (mean Temperature of July). The results are simulated with Envimet model.*

To standardize data collection, debate is needed on the most useful summary temperature parameters, such as daily average, average during daylight hours and/or difference at the warmest time of day, as well as the number of sites and method of site selection, in order to best describe temperature differences between green and representative non-green areas. [11]
There are several scientific works related to measures to reduce heat stress in cities that provide the above-mentioned additional information. [9] [11] [12] [13] [14] [15] [16][17] .

Additional information for heat reduction measures

- **Type of evidence** (optional). The results are obtained from:
    - Experimental/field study
    - Theoretical study
    - Simulation study (numerical models)
- **Meteorological situation** (optional). Specified if the results are calculated in a situation of heat wave, mean conditions day, etc.

  Depending on the measure, a type of meteorological data must be necessary. For example, the climatic situation of a heat wave day, the average of a certain month in summer and/or in winter, the maximum or minimum of a certain period, an average of the whole year, the data over a day, etc. These data are not essential for comparison or standardization, but it is recommendable in order to know if a measure works in normal meteorological conditions, during a heat wave, etc.
- **Baseline scenario** (highly recommended) specifies the reference situation (the same situation without the adaptation option). The effectiveness of a measure must be calculated comparing it with a reference situation or with the same situation without the adaptation option. The baseline scenario must be specified.

  For certain green options, the choice of the baseline scenario can lead to a different result as, for example, the difference of the air temperature between the middle of a park and the surroundings of it can differs more than 2 ºC if the comparison is made between the middle of the park and city centre.
- **Time expression of the results** (highly recommended). The results of the effectiveness variables can be given in different ways depending on the objective: in a certain moment of the day, as an average of day, daily average, etc.
- **Location where the results are achieved** (highly recommended). The location where the results are achieved should be specified. For example, for green facades the distance from the façade where the reduction of temperature is given must be specified.

– Pluvial flood

The aim is indicating the effectiveness of the measures regarding pluvial flooding impacts. There are different variables to measure the pluvial floods reduction options, depending on the measure applied.
As with the heat reduction measures, other relevant parameter must be specified in order to make measures comparable. In this case there are also scientific works related

that provide this information. [9][13][18] [19][20][21][22][23]

Additional information for pluvial reduction measures

- **Type of evidence** (optional). The results are obtained from:
    - Experimental/field study
    - Theoretical study
    - Simulation study (numerical models)
- Meteorological situation (optional):

  For pluvial flooding reduction options the characteristics of the rainfall or storm event can be specified. The characteristics to specify will depend on the measure to apply. The rainfall characteristic are duration, intensity, frequency and some authors use the location of the rainfall expressed as the time to peak ratio (ratio of the time before the peak intensity to the total duration).
- **Baseline scenario** (highly recommended):

  The effectiveness of a measure must be calculated comparing it with a reference situation or with the same situation without the adaptation option. In this case the baseline scenario can be a conventional drainage system, conventional roof, etc.
- Time expression of the results (highly recommended):

  The moment in which the variable measurement is done must be specified. The variable measurement is done during a period of time that varies from 24 hours, the duration of the event or a certain period of time after the rainfall stops. Usually the period of time given, after the rainfall starts are 10 mins. Others can be the first 10 min, 24 h period immediately following the rainfall, runoff volume (ml) every 20 mins during the first 3 hours of the storm event, the first 10 min, 24 h period immediately following the experiment, etc.

– Fluvial flooding

Reduce the peak discharge of a river overflow.
Additional information for fluvial reduction measures:

- Meteorological information
- Baseline scenario
- Time expression of the results

– Wind storm

Reduce the wind speed.
Additional information for fluvial reduction measures:

- Meteorological information
- Baseline scenario
- Time expression of the results

4.3.3 Vulnerability reduction

It will analyse the vulnerability of receptors to the following hazards:

– Heat [24] [25] [26]

  Indicate the exposure, sensitivity and adaptive capacity variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of:

  - The gradual increase of the temperature (↑Tª 2100, ...),
  - Extreme climate event (Heat wave),
  - Urban Heat Island (UHI) effect.

– Pluvial flood [8] [26]

  Indicate the exposure, sensitivity and adaptive capacity variables considered in the estimation of the effectiveness of adaptation options (reduced exposure) related to the climate hazard of oluvial flood

– Fluvial flood [25] [26]

  Indicate the exposure, sensitivity and adaptive capacity variables considered in the estimation of the effectiveness of adaptation options (reduced exposure) related to the climate hazard of fluvial flooding

– Sea level rise and storm surge [26] [27]

  Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of sea level rise and storm surge.

  In this field are included the exposure indices related to:

  - The gradual increase of the sea level (↑ m. 2100,...),
  - Extreme climate event (storm surge).

  This information must be related to the threats mentioned in "Impact on hazard"

– Drought [25]

  Indicate the exposure, sensitivity and adaptive capacity variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of drought

– Wind storm [26]

  Indicate the exposure, sensitivity and adaptive capacity variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the hazard of wind storm

The aim of vulnerability assessment is not only to predict hotspots, but also to identify vulnerable groups those are most susceptible to experience the adverse impacts of climate change.

- Exposure [1] [8]

  Exposure refers to the nature and degree to which a system (people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets) is exposed in places that could be adversely affected to significant climatic variations. The effectiveness of adaptation options can be expressed in terms of reduced exposure.
  Example of index related to the exposure to heat: number of people that will be exposed to the heat wave, share of urban green spaces (exposed) including the urban fringe, and urban element exposed (Buildings, Energy, Water, Transport, etc.).
  Example of index related to the exposure to flood (pluvial/fluvial/sea level rise & storm surge): urban area flooded by precipitation (100 year event), share of urban green spaces (exposed) including the urban fringe, economic activities exposed (primary, secondary, tertiary for district), urbanised area per core city affected, etc.
  Example of index related to the exposure to drought: number of people that will be exposed to the drought, percentage of water supply not directly dependent on rainfall, etc.
  Example of index related to the exposure to wind storm: number of affected assets, infrastructures or buildings, economic activities exposed (primary, secondary, tertiary for district.).

- Sensitivity [1] [8]

  Measure the nature and degree to which a system (people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets) is adversely affected by significant climatic variations. Unlike exposure, sensitivity relates to the intrinsic characteristics of a system. The sensitivity is determined by the number and type of sensitive elements in the system (such as people, ecosystems, infrastructure, etc.) and the sensitivity of these elements to impact or damage. The effectiveness of adaptation options is thus expressed in terms of reduced sensitivity.
  Example of index related to the sensitivity to heat: soil sealing, green and blue distribution, green facades and roofs, shadowing and ventilation, demographic dependency (ratio >65 and <20), etc.
  Example of index related to the sensibility to flood (pluvial/fluvial/sea level rise & storm surge): percentage of critical infrastructure, buildings areas, industrial/commercial areas, etc. in floodable zone, share of people with disabilities, health problems, social dependency for mobility, share of protected areas (wetlands) within the Urban Morphological Zone, etc.
  Example of index related to the sensibility to drought: Water consumption per capita (average per year), share of sensitive population groups, density of swimming pool, etc.

- Adaptive capacity [1] [8]

  Adaptive capacity is the ability of a systems, institutions, humans, and other organisms to adjust to potential damage (including climate variability and extremes), to take advantage of opportunities, or to respond to consequences. A good capacity for adaptation can decrease the overall vulnerability to a climate threat and increase resilience. The effectiveness of adaptation options can be expressed in terms of increased adaptive capacity.

Example of index related to the adaptive capacity to heat: percentage of green surface (green factor), share of people with university studies (tertiary studies), green/blue urban area [%] UMZ of core city, municipal budget and municipal economic dependence, availability of HVAC, etc.

Example of index related to adaptive capacity to flood (pluvial/fluvial/sea level rise & storm surge): protection systems against floods, emergency planning (floods), policy framework, institutional coordination and social participation, etc.

Example of index related to adaptive capacity to drought: ratio between water consumption for household uses and assimilated "industrial + commercial" uses, Shanon diversity index, water rationing and water cuts, etc.

Example of index related to adaptive capacity to wind storm: potential use of renewable energy.

– Overall vulnerability

  In case it is not possible to disaggregate the vulnerability in sensitivity and adaptive capacity, it will be possible to include information of the overall vulnerability. Include vulnerability reduction for every threat (heat, pluvial and fluvial flood, sea level rise and storm surge, drought and wind storm).

4.3.4 Impact radius

How far does the influence of the option reach?

– very limited (< 1 m)
– short distance (1-10 m)
– medium (10-100 m)
– long distance (100-1,000 m)

4.3.5 Robustness [8]

Positive effects of some adaptation measures can even be reached without climate change. No-regret options are interventions with positive outcomes for development even in situations in which the uncertainty surrounding the future impacts does not allow for better targeting of the policy responses:

– No-regret: no-regret actions are cost-effective under current climate conditions and are consistent with addressing risks of climate change, they possess no hard trade-offs with other policy objectives.
– Low-regret: low-regret actions are relatively low cost and provide relatively large benefits under predicted future climates.
– Win-win: win-win actions contribute to adaptation whilst also having other social, economic and environmental policy benefits, including those relating to mitigation.

4.3.6 Flexibility

It refers to the potential for adjustments to different climate scenarios and socioeconomic developments. The adaptation options allowed easy adjustments and incremental implementation if conditions changed or if changes are different from those expected today. In this sense, adjustable options should be able to be adapted to different climate scenarios as well as socio-economic development trends. (Example for measurement: Does the proposed options take sufficient consideration of the uncertainty aspect of climate change? Do the options remain useful under less or unexpected manifestations of climate change? Can the options easily be adapted if conditions are changing or different? This information can be obtained through expert and stakeholder judgement.

4.3.7 Time [1][8]

- Implementing-Time: It refers to the required time to implement the measure
- Effective-time: It refers to the required time to start being effective the measure
- Effective life-time or sustainability: Time span during which the adaptation practice keeps on being effective, after having been implemented. The likelihood that benefits/outcomes of the adaptation options/ adaptation process will continue for an extended period of time after the project completion, as well as the ability of stakeholders to continue the adaptation processes beyond project lifetimes. Sustainable development is expected to minimise the threats posed by the impacts of climate change and to capitalise on the potential opportunities presented by it, and bring benefits in terms of alleviating pre-existing problems (no-regret).

4.3.8 Side-effect [8]

It refers to co-lateral effects. The side effects are positive and negative. Negative (also referred to as maladaptation) are indirect, negative outcomes set off by the options outside of the target. Positive (effects) are additional beneficial outcomes delivered by the options but not aimed at in the first place.

- Economical: Effects on innovation and competitive advantage; effect on employment
- Environmental: Synergies with mitigation, positive environmental effects (biological, diversity,…), avoiding maladaptation
- Social: Distributional impacts (different social or economic groups)
- Health

4.3.9 Uncertainty

It refers to the evaluated costs and benefits. Future prices, wages, inflation and discount rates used need to be referenced. Use a data quality rating system: [28]

- An estimate based on a large amount of information fully representative of the situation and for which all background assumptions are known.
- An estimate based on a significant amount of information representative of most situations and for which most of the background assumptions are known.
- An estimate based on a limited amount of information representative of some

situations and for which background assumptions are limited.

- An estimate based on an engineering calculation derived from a very limited amount of information representative of only one or two situations and for which few of the background assumptions are known.
- An estimate based on an engineering judgement derived only from assumptions.

4.4 Efficiency (Table 8)

This field considers not only the benefits (economic and non-economic) gained from adaptation options, but also the costs (the direct and external costs),the co-benefits of the measure (that can be related to the multifunctionality and/or the ecosystem services provided), the associated uncertainty and the combinability.

4.4.1 Investment cost

It refers to the additional cost relative to the "base case" (the situation in which the adaptation measure has not been installed). Provide the year that applies cost data, currency exchange rates and discount rate used in the calculations.

- Direct cost: [8][28]
  - Investment expenditure: adaptation equipment expenditure, installation expenditure.
  - Annual operating and maintenance costs: energy costs, materials and services costs, labour costs. fixed operating/maintenance costs.
  - Costs of administrative implementation of adaptation options.
- Indirect or external costs (environmental and social costs, time saved, health...).

4.4.2 Benefit [8][29][30]

In this criterion we separate ex-ante (base case) and post-ante adaptation options. Benefits of an adaptation intervention should include the avoided damages from climate change impacts and co-benefits, where relevant. If there is no market for the goods or services provided by the adaptation activity, benefits can be estimated in indirect ways through nonmarket-based approaches, such as contingent evaluation.

- Economic: monetary benefits resulting from the activity developed. Net Economic Benefits.
- Environmental: positive side-effects on environment (for example: water savings).
- Social: positive side-effects on society (for example: cohesion, equity, quality of life).
- Health: benefits associated to reduced stress, mortality or morbidity.

4.4.3 The relationship between cost and benefit [29] [31] [32] [33] [34] [30]

- Cost-benefit analysis: [8][30][**¡Error! Marcador no definido.**][33][34]

Economic viability of adaptation options in terms of their costs and benefits ratio. Adaptation options are assessed based on whether they can reach their objectives in the most efficient way in economic terms (e.g. they achieve objectives at least cost) and have a balanced cost/benefits ratio. The benefits of adaptation options are compared to costs and effort. A CBA is basically comparing costs and benefits of an intervention over time.

- Cost-effectiveness: [33][**¡Error! Marcador no definido.**][**¡Error! Marcador no finido.**]

  It determines how a well-defined objective can be achieved in the most cost-efficient way. Costs need to be quantified in monetary terms to conduct a CEA. The procedure is identical to the cost assessment used in a CBA. It is not possible to assign a monetary value to benefits. Therefore, the unit in which benefits are measured has to be carefully defined.

- Multi-criteria analysis [30][33]

  It consists on a qualitative assessment of criteria (such as feasibility, cost effectiveness, co-benefits, ease of implementation, acceptability to local population and resources required…).

4.4.4 Co-benefit [9]

Describes if a measure has benefits in a single-hazard or more hazards (multi-hazard)

4.4.5 Uncertainty

It refers to the evaluated costs and benefits. Future prices, wages, inflation and discount rates used need to be referenced. Use a data quality rating system [28][**¡Error! Marcador no definido.**]:

- An estimate based on a large amount of information fully representative of the situation and for which all background assumptions are known.
- An estimate based on a significant amount of information representative of most situations and for which most of the background assumptions are known.
- An estimate based on a limited amount of information representative of some situations and for which background assumptions are limited.
- An estimate based on an engineering calculation derived from a very limited amount of information representative of only one or two situations and for which few of the background assumptions are known.
- An estimate based on an engineering judgement derived only from assumptions.

4.4.6 Combinability [9][35] [36] [37]

Take into account the combinability: to what extend can the measure be integrated and combined with other adaptation measures? This information can be obtained through expert and stakeholder judgement.

- Measure has little possibility for integration.
- Measure can be combined and complement but to a limited extent.
- Measure can complement / combine with certain measures in water sector.
- Can complement / combine with a variety of measures in water sector.
- Can complement / combine with other measures of different sectors.

5. Entity–Relationship Model

Taking into account the contents previously described and the possible uses that may be arisen in the project, a first approach to the structure of the database has been made, as a first step before implementing it physically. To do so, an entity-relationship model has been designed.

In the diagram showed in Figure 1 each box represents an entity of the model and the lines that connect those entities represent relationships among them and its cardinality (one to one, one to many or many to many). At the same time, every entity has a set of attributes that characterizes it.

To ease the visual identification of the entities of the model with the type of information already described in this document, and although this has not implications in the database structure itself, the entities have been distributed in the diagram according to the four main components of the RESIN option catalog: General information, Organisation, Effectiveness and Cost-efficiency.

Some of the entities are accompanied by an image ( ), which means that the table to include later into the database will be able to store data from a user with privileges of editing information about specific adaptation options (addition, elimination or modification). The rest of the tables will store data that only may be modified by a database administrator.

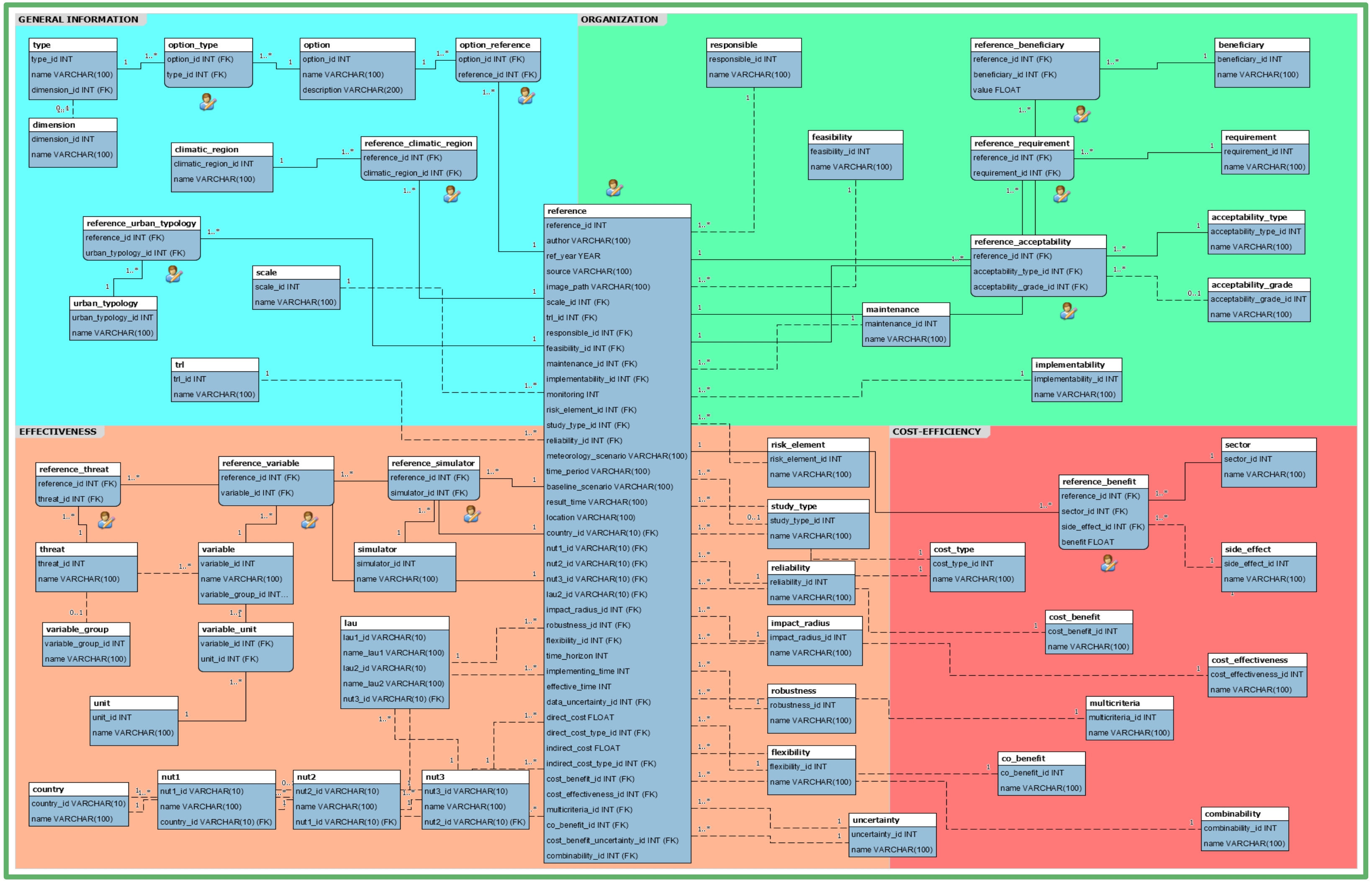

Figure 1. Entity–Relationship model of the option database

6. Annex: the database structure in a spreadsheet

Table 1.General information

Dimension	Description	Variables	Units	Reference: literature
Title	Name of the adaptation option	na	Text	
General description	Short description of the option (aim, functioning, etc.)	na	text	
Image/photo	visualisation of the option	na	image/photo	
Climate threat	The climate hazard(s) addressed by the option check with Jeremy definitions in WP1 report	* Heat waves; * Pluvial flooding; * Fluvial flooding; * Sea level rise & storm surge; *Drought; * Wind storm;	Check box (multiple category choice)	[1][2][3][8] [24] [38] [39] [40] [41] [42]
Type	Describes the dimension of the options, classifying in different types. This categorization aims to take into account the diversity of adaptation options for different sectors and stakeholders. Some options cut across several categories. Furthermore, some adaptation options are interrelated. * Structural/Physical: Engineering and built environment (Grey), Technological, Ecosystem based (Green-Blue) and services oriented * Social: Educational, Informational and Behavioral * Institutional: Economic, Laws and regulations, Government policies and programs	* Structural/Physical: Engineered and built environment (Grey * Technological * Ecosystem based: green * Services * Educational * Informational * Behavioral * Economic * Laws and regulations * Government policies and programs	Check box (multiple category choice)	[1]
Geography	Climatic region(s) to which the option be applied. Climate change regions (not only climate regions) are regions with similar climate change characteristics and derive from a cluster analysis of 8 climate change variables	* Southern-Central Europe * Northern Europe * Northern-Central Europe * Mediterranean region * Northern-western Europe	Check box (multiple category choice)	[2][3]
Scale	Scale of implementation of option: * At the urban scale, components and parameters for architectural and spatial quality include infrastructure, urban form, proximity to facilities and functions, access to green areas, building typology and morphology, transition between different urban areas and city boundaries. * At the building scale, examples include views, isolation and contact, internal and external arrangements, transition between public and private domain and perceived density.	* Building/ infrastructure * Building block/ garden /square * Street * District/ Neighbourhood * Village/city * Land use zoning * Region * Nation	Check box (single choice)	[39]
Sector	Sector(s) for which the option can provide a solution	*Critical Infrastructure (Transport: road, rail, air, Inland waterways, ocean and short-sea shipping and ports; Energy: electricity, oil, gas; Green infrastructure), * Construction * Water * Waste * ICT * Industry * Health * Primary sector	Check box (multiple category choice)	[43] [44] [45]
Technology Readiness Level	Technology maturity of the option	1. Basic principles observed 2. Technology concept formulated 3. Experimental proof of concept 4. Technology validated in lab 5. Technology validated in relevant environment 6. Technology demonstrated in relevant environment 7. System prototype demonstration in operational environment 8. System complete and qualified 9. Actual system proven in operational environment	Check box (single choice)	[45]
Urban typology	to be included later			

Table 2.Effectiveness: Main element and Impact

Dimension	Subdimension	Description	Variables	Units	Reference: literature
Main element of concern	-	Which element of vulnerability does the option influence most?	*Magnitude of the Impact derived from the hazard * Exposure * Sensitivity * Adaptive capacity	Check box (single choice)	
Impact magnitude reduction	Heat	Reducing the temperature derived parameters caused by heat increasing. Other relevant information that must be specified for the heat reduction measures -Type of evidence (optional): The results are obtained trought - Experimental/field study - Theoretical/anecdotical study - Simulation study (numerical models) -Meteorological situation (optional): specified if the results are calculated in a situation of heatwave, mean conditions day, etc. -Baseline scenario (highly recomended): specify the reference situation (the same situation without the adaptation option) -Time expression of the results (highly recomended): specify if the results correspond with a certain moment of the day, average of the day, average of the morning, etc. -Location where the results are achieved (highly recomended)	* Reduction in air temperature/UHI * Improve outdoor thermal comfort * Increased evapotranspiration * Increased ventilation/wind * Reduced overheating indoors/indoor comfort	* °C * °C, PET, PMV * mm/day (ET) * (m/sg) * Adjusted ATG; ºC	[11][12][13] [14][15][16] [14][17][9]
	pluvial flooding	Reducing the magnitud of flooding caused by extreme precipitation events and water retention. Other relevant information that must be specified for the pluvial flooding reduction measures -Type of evidence (optional): The results are obtained trought - Experimental/field study - Theoretical study - Simulation study (numerical models) -Meteorological situation (optional): specified the characteristics of the rainfall (duration, intensity, frecuency) and location of the rainfall expreesed as the ime to peak ratio (ratio of the time before the peak intensity to the total duration). -Baseline scenario (highly recomended): specify the reference situation (the same situation without the adaptation option), conventional drainage system, conventional roof, etc. -Time expression of the results (highly recomended):The variable measurement is done during a period of time that varies from 24 hours, the duration of the event or a certain period of time after the rainfall stops. Usually the period of time given, after the rainfall starts are 10 mins.	* Reduction of water volume on street * Retention * Surface runoff reduction * Reduction of peak discharge * Increasing infiltration	* m3 * m3, % of rainfall, % of retention needed * mm, kg m-2 s-1', % of reduction needed * m3/s * m2 green/blue, m3	[18][13][9] [19][21][23]
	fluvial flooding	Reducing the peak discharge of a river overflow. Other relevant information: specify all the information available -Meteorological information -Baseline scenario -Time expression of the results	* Reduction of peak discharge	* m3/s	
	wind storm	Reduce the wind speed. Other relevant information: specify all the information available -Meteorological information -Baseline scenario -Time expression of the results	* Variation of wind speed	* m/sg	

Table 3.Effectiveness: Exposure

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
Impact on exposure; [1][8] Exposure refers to the nature and degree to which a system (people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets) is exposed in places that could be adversely affected to significant climatic variations. The effectiveness of adaptation options can be expressed in terms of reduced exposure. (Example of index related to the exposure to heat: number of people that will be exposed to the heat-wave, share of urban green spaces (exposed) including the urban fringe, Urban element exposed (Buildings, Energy, Water, Transport, ...). Example of index/indices related to the exposure to Flood (pluvial/fluvial/sea level rise & storm surge): Urban area flooded by precipitation (100 year event), share of urban green spaces (exposed) including the urban fringe, Economic activities exposed (primary, secondary, tertiary for district), Urbanised area per core city affected, ... Example of index related to the exposure to Drought: Number of people that will be exposed to the drought, percentage of water supply not directly dependent on rainfall, ... Example of index related to the exposure to Wind storm: Nº of affected assets: infrastructures or buildings, economic activities exposed (primary, secondary, tertiary for district.)	Heat (In this field are included the exposure indices related to: * The gradual increase of the temperature (↑Tª 2100, ...), * Extreme climate event (Heat Wave), * Urban Heat Island (UHI) effect. This information must be related to the threats mentioned in "Impact on hazard"	Indicate the exposure variables, considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of heat	* Number of people that will be exposed * Share of urban green spaces (exposed) including the urban fringe * Economic activities exposed (primary, secondary, tertiary for district) * Urban element / Infraestructures exposed (Buildings, Energy, Water, Transport, ...) * The edge density between green and non-green (i.e. "red") Space	* Nº of people * Nº of activities * Sqaure meter * Total resident population per sqaure km * % change * € -Land price or value of the properties	[25] [26] [46]
	Pluvial Flood	Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure) related to the climate hazard of Pluvial Flood	* Urban area flooded by precipitation (100 year event) * Percentage of the UMZ that would be flooded (100 year event) * Share of urban green spaces (exposed) including the urban fringe * Population exposed * Economic activities exposed (primary, secondary, tertiary for district) * Urban element / Infraestructures exposed (Buildings, Energy, Water, Transport, ...)	* Nº of people * Nº of activities * Sqaure meter * Total resident population per sqaure km * % change * € -Land price or value of the properties	[6] [25] [26] [27] [47] [48]
	Fluvial flooding	Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure) related to the climate hazard of Fluvial Flooding	* Urban area flooded by rivers (100 year event), * Percentage of the UMZ that would be flooded (100 year event) * Degree of soil sealing (pluvial flooding) * Share of urban green spaces (exposed) including the urban fringe * Population exposed * Urban element / Infraestructures exposed (Buildings, Energy, Water, Transport, ...) * Economic activities exposed (primary, secondary, tertiary for district)	* Nº of people * Nº of activities * Sqaure meter * Total resident population per sqaure km * % change * € -Land price or value of the properties	[25] [26] [47] [48] [**¡Error! Marcador o definido.**]
	Sea level rise & storm surge In this field are included the exposure indices related to: * The gradual increase of the sea level (↑m. 2100, ...), * Extreme climate event (Storm surge). This information must be related to the threats mentioned in "Impact on hazard"	Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of Sea level rise & storm surge	* Urbanised area per core city affected * Share of urban green spaces (exposed) including the urban fringe * Population exposed * Urban element / Infraestructures exposed (Buildings, Energy, Water, Transport, ...) * Economic activities exposed (primary, secondary, tertiary for district) * Land less than 10m above sea-level (%)	* m2 * % * Nº of people * Nº of activities * € -Land price or value of the properties	[25] [26] [27] [47] [48] [**¡Error! arcador no definido.**]
	Drought	Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the climate hazard of drought	* Number of people that will be exposed to the drought * Percentage of water supply not directly dependent on rainfall (i.e. percentage of supply from groundwater or desalination plants) * Water exploitation index (WEI) * Ground water area * Economic activities exposed (primary, secondary, tertiary for district)	* nº of people * m3 * % * € -Land price or value of the properties	[25] [26] [**¡Error! arcador no definido.**] [50]
	Wind storm	Indicate the exposure variables considered in the estimation of the effectiveness of adaptation options (reduced exposure), related to the hazard of Wind storm	* Nº of affected assets: infrastructures or buildings * Urbanised area affected * Economic activities exposed (primary, secondary, tertiary for district) * Urban element / Infraestructures exposed (Buildings, Energy, Water, Transport, ...)	* nº * m2 * € -Land price or value of the properties	

Table 4.Effectiveness: Sensibility

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
Impact on Sensitivity. [1][8] Measure the nature and degree to which a system (people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets) is adversely affected by significant climatic variations. Unlike exposure, sensitivity relates to the intrinsic characteristics of a system. The sensitivity is determined by the number and type of sensitive elements in the system (such as people, ecosystems, infrastructure, etc.) and the sensitivity of these elements to impact or damage. The effectiveness of adaptation options is thus expressed in terms of reduced sensitivity. Example of index related to the sensitivity to heat: soil sealing, green and blue distribution, green facades and roofs, shadowing and ventilation, demographic dependency (ratio >65 and <20), ... Example of index related to the sensibility to Flood (pluvial/fluvial/sea level rise & storm surge): percentage of critical infrastructure, buildings areas, Industrial/commercial areas, etc. in floodable zone, share of people with disabilities, health problems, social dependency for mobility, share of protected areas (wetlands) within the Urban Morphological Zone,... Example of index related to the sensibility to drought: water consumption per capita (average per year), share of sensitive population groups, density of swimming pool, ...	Heat	Indicate the sensitivity variables considered in the estimation of the effectiveness of adaptation options (reduced sensitivity), related to the hazard of heat waves, classifying each variable in different fields of actuation, HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** * Population density / Demographic dependency (ratio >65 and <20) / Share of senior citizens with age >65 years / Share of unemployed, beneficiaries of the minimum insertion incomes, etc./ Share of poor people, e.g. percentage of households with less than half the national average income / Share of people with disabilities / Share of households integrated by only one member / Mortality rate * Cooling water demand / Peak power consumption * Penetration of aur-conditioning systems **GOVERNANCE** **SOCIO-ECONOMIC** * Dependence of economic activity * Employment level provided by economic activity **BUILT ENVIRONMENT** * nº of improved insulation of buildings * nº of CI * Quality of the building (isolation) * Housing type (age of building, ...) / Percentage of substandard housing (house with area < 20 m2) / ... * Soil sealing / Green and blue distribution, green facades and roofs, shadowing and ventilation * Percentage of substandard housing (house with area < 20 m2) **NATURAL CAPITAL** * Dependence of the population to environmental resources * Number of days ozone O^3 concentrations exceed 120 µg/m³ * Accumulated ozone concentration in excess 70 µg/m³ **PREVIOUS IMPACT** * Number of calls and Attentions for (Social and medical) Emergencies (Average per month)	* HUMAN CAPITAL (%; Nº; Kwh; hab/km2;) * GOVERNANCE (nº) * SOCIO-ECONOMIC (Nº; %;) * BUILT ENVIRONMENT (%; Number; Age of building;) * NATURAL CAPITAL (%;) * PREVIOUS IMPACT (Nº;)	[24] [25] [26] [47] [48]
	Pluvial Flood	Indicate the sensitivity variables (index/indices!?), considered in the estimation of the effectiveness of adaptation options (reduced sensitivity), related to the hazard of pluvial flood, classifying each variable in different fields of actuation, ENVIRONMENTAL, ECONOMIC, PHYSICAL, SOCIAL, CULTURAL (HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** * Share of protected areas (wetlands) within the Urban Morphological Zone * Population density * Share of people with disabilities, health problems, social depedency for mobility ... **GOVERNANCE** * Number of UNESCO sites at risk **SOCIO-ECONOMIC** * Dependence of economic activity * Employment level provided by economic activity **BUILT ENVIRONMENT** * Mean soil sealing [%] of UMZ of core city * nº of CI * nº and type of old building and infraestructure (age, ...) * Percentage of critical infraestructure, buildings areas, **buillding industry, transport, human health, water energy, tourim, and industry and commerce infraestructures..**. in floodable zone * Number of sensible hotspot (hospital, school, kindergartens) * Quality of drainage infrastructure * Energy at risk	* HUMAN CAPITAL (%; hab/km2;) * GOVERNANCE (Nº;) * SOCIO-ECONOMIC (Nº; %;) * BUILT ENVIRONMENT (%; Nº, age of building; Kwh;) * NATURAL CAPITAL (%;) * PREVIOUS IMPACT (Nº; Nº/year;)	[24] [25] [26] [27] [47] [50]

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
			* Roads paved (%) * Position of barrages (m) **NATURAL CAPITAL** * Dependence of the population to environmental resources **PREVIOUS IMPACT** * Number of Actuations/Emergencies of the Water Departament (Average per month). * Frequency of floods per unit area (1) Land area (sq. km) (2) International Disaster Database		
	Fluvial flooding		See "Pluvial Flood"	See "Pluvial Flood"	
	Sea level rise & storm surge		See "Pluvial Flood"	See "Pluvial Flood"	
	Drought	Indicate the sensitivity variables (index/indices!?), considered in the estimation of the effectiveness of adaptation options (reduced sensitivity), related to the hazard of drought, classifying each variable in different fields of actuation, ENVIRONMENTAL, ECONOMIC, PHYSICAL, SOCIAL, CULTURAL (HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT (or better than "field of actuation" --> "repector / domain response" !?)	**HUMAN CAPITAL** * Water consumption per capita (average per year) * Share of sensitive population groups * Share of protected areas (wetlands) within the Urban Morphological Zone **GOVERNANCE** *** Water supply (not or yes) directly dependent on rainfall** **SOCIO-ECONOMIC** * Balance between economic activities building and residential: Percentage of buildings of economic activities in consolidated urban land. * **Energy production (not or yes) dependent on water** *** Crop type (Areas)** *** Irrigation systems (Areas)** **BUILT ENVIRONMENT** * Density of swimming pool **NATURAL CAPITAL** * Total area covered by wetlands within the Urban Morphological Zone * Share of protected areas (wetlands) within the Urban Morphological Zone **PREVIOUS IMPACT**	* HUMAN CAPITAL (l/hab/año; %) * GOVERNANCE ( ) * SOCIO-ECONOMIC (%;) * BUILT ENVIRONMENT (Nº/ha) * NATURAL CAPITAL (Ha (m2);) * PREVIOUS IMPACT ( )	[24] [25] [47] [50]
	Wind storm	Indicate the sensitivity variables (index/indices!?), considered in the estimation of the effectiveness of adaptation options (reduced sensitivity), related to the hazard of wind storm, classifying each variable in different fields of actuation,ENVIRONMENTAL, ECONOMIC, PHYSICAL, SOCIAL, CULTURAL (HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT (or better than "field of actuation" --> "repector / domain response" !?)	HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	HUMAN CAPITAL ( ) GOVERNANCE ( ) SOCIO-ECONOMIC ( ) BUILT ENVIRONMENT ( ) NATURAL CAPITAL ( ) PREVIOUS IMPACT ( )	

Table 5.Effectiveness: Adaptive capacity

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
Adaptive capacity. [1][8] Adaptive capacity is the ability of a systems, institutions, humans, and other organisms to adjust to potential damage (including climate variability and extremes), to take advantage of opportunities, or to respond to consequences. A good capacity for adaptation can decrease the overall vulnerability to a climate threat and increase resilience. The effectiveness of adaptation options can be expressed in terms of increased adaptive capacity.(Example of index/indices related to the adaptive capacity to heat: Percentage of green surface (green factor), Share of people with university studies (tertiary studies), green/blue urban area [%] UMZ of core city, municipal budget and municipal economic dependence, availability of HVAC, etc.. Example of index related to adaptive capacity to Flood (pluvial/fluvial/sea level rise & storm surge): protection systems against floods, emergency planning (floods), policy framework, institutional coordination and social participation, etc. Example of index related to adaptive capacity to Drought: ratio between water consumption for household uses and assimilated "industrial + commercial" uses, Shanon diversity index, water rationing and water cuts, etc. Example of index related to adaptive capacity to Wind storm: potential use of renewable energy.	Heat	Indicate the adaptative capacity variables considered in the estimation of the effectiveness of adaptation options (increased adaptive capacity), related to the hazard of heat waves, classifying each variable in different fields of actuation, HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** * Improvements on population awareness * Rate of neighborhood associations * Rate of Health centers, ambulatory, ... * Share of people with university studies (tertiary studies) * Sanitary accessibility * Capacity of behavior and expert decision-making * Citizen Coordination * Electoral Participation **GOVERNANCE** * Policy framework / institutional coordination and social participation * Governance indicator * Change in land use planning policies **SOCIO-ECONOMIC** * Disposable income per capita * Municipal budget and municipal economic dependence * Transferability (adaptive capacity) - long term **BUILT ENVIRONMENT** * Availability of HVAC ("Heating, Ventilating and Air Conditioning") * Sanitary accessibility (time) * Adaptive potential of buildings and infrastructure * Opportunities for development (land) **NATURAL CAPITAL** * Green/blue urban area [%] UMZ of core city * Green area per capita (m2/hab) * Percentage of green surface (green factor) * Resilience of natural ecosystems (municipal biodiversity index) **PREVIOUS IMPACT** * risk trainig * Response capacity of emergency- heat waves (based on experience) * Emergency planning (heat waves) * Adaptative know-how	* HUMAN CAPITAL (%;) * GOVERNANCE (Nº; %;) * SOCIO-ECONOMIC (€;) * BUILT ENVIRONMENT (Nº/hab; m2 (or m3); hour;) * NATURAL CAPITAL (%; m2/hab; Nº;) * PREVIOUS IMPACT (Nº; %;)	[24] [26] [27] [47] [48] [50]
	Pluvial Flood	Indicate the adaptative capacity variables considered in the estimation of the effectiveness of adaptation measures (increased adaptive capacity), related to the hazard of Pluvial Flood, classifying each variable in different fields of actuation, HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** * Electoral Participation * Population with access to reliable electricity (%) **GOVERNANCE** *Capacity of behavior and expert decision-making * Citizen Coordination * Policy framework / institutional coordination and social participation * Governance indicator * Change in land use planning policies **SOCIO-ECONOMIC** * Municipal budget and municipal economic dependence * Transferability (adaptive capacity) - long term **BUILT ENVIRONMENT** * Protection systems against floods * Opportunities for development (land) * Adaptive potential of buildings and infrastructure * Technical flood protection measures * Sanitary accessibility (time)	* HUMAN CAPITAL (%;) * GOVERNANCE (%; Nº;) * SOCIO-ECONOMIC (€ ;) * BUILT ENVIRONMENT (Nº; m2 (or m3); time;) * NATURAL CAPITAL (%; Nº;) * PREVIOUS IMPACT (%; Nº;)	[26] [27] [47] [50]

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
			NATURAL CAPITAL * Green/blue urban area [%] UMZ of core city * Resilience of natural ecosystems (municipal biodiversity index (number of different biotopes)) **PREVIOUS IMPACT** * Emergency planning (floods) * Adaptative know-how (AL21 experience) * Early warning related activities (monitoring system or emergency plans) * Change in the proportion of soil sealing * risk trainig * Response capacity of emergency- floods (based on experience)		
	Fluvial flooding		See "Pluvial Flood"	See "Pluvial Flood"	
	Sea level rise & storm surge		See "Pluvial Flood"	See "Pluvial Flood"	
	Drought	Indicate the adaptative capacity variables considered in the estimation of the effectiveness of adaptation options (increased adaptive capacity), related to the hazard of Drought, classifying each variable in different fields of actuation, HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** **GOVERNANCE** * Water rationing and water cuts * Governance indicator * Change in land use planning policies **SOCIO-ECONOMIC** * Diversity index of industrial activities (Shanon diversity index) * Access to efficient irrigation technology **BUILT ENVIRONMENT** * Ratio between water consumption for household uses and assimilated "industrial + commercial" uses. **NATURAL CAPITAL** * Green/blue urban area [%] UMZ of core city * Resilience of natural ecosystems (municipal biodiversity index (number of different biotopes)) **PREVIOUS IMPACT** * Emergency planning (droughts)	* HUMAN CAPITAL ( ) * GOVERNANCE (Nº;) * SOCIO-ECONOMIC ( ) * BUILT ENVIRONMENT (%;) * NATURAL CAPITAL ( ) * PREVIOUS IMPACT (Nº;)	[25] [26] [47] [50]
	Wind storm	Indicate the adaptative capacity variables considered in the estimation of the effectiveness of adaptation options (increased adaptive capacity), related to the hazard ofWind storm, classifying each variable in different fields of actuation, HUMAN CAPITAL, GOVERNANCE, SOCIO-ECONOMIC, BUILT ENVIRONMENT, NATURAL CAPITAL, PREVIOUS IMPACT	**HUMAN CAPITAL** **GOVERNANCE** * Governance indicator * Change in land use planning policies **SOCIO-ECONOMIC** **BUILT ENVIRONMENT** **NATURAL CAPITAL** * Potential use of renewable energy **PREVIOUS IMPACT** * Emergency planning (wind storm)	* HUMAN CAPITAL ( ) * GOVERNANCE ( ) * SOCIO-ECONOMIC ( ) * BUILT ENVIRONMENT ( ) * NATURAL CAPITAL (m/s;) * PREVIOUS IMPACT (Nº;)	[26] [50]

Table 6.Effectiveness: Others

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
Overall vulnerability	-	In case it is not possible to disaggregate the vulnerability in sensitivity and adaptive capacity, it will be possible to include information of the overall vulnerability.	* Heat vulnerability reduction * Pluvial flood vulnerability reduction * Fluvial flood * Sea level rise and storm surge vulnerability reduction * Drought vulnerability reduction * Wind storm vulnerability reduction	* % * m2	
Impact radius		How far does the influence of the option reach?	* very limited (< 1m) * short distance (1-10 m) * medium (10-100 m) * long distance (100-1000 m)	Check box (single choice)	
Robustness	-	Positive effects of the adaptation options are even reached without climate change. No-regret actions are cost-effective under current climate conditions and are consistent with addressing risks of climate change, they possess no hard trade-offs with other policy objectives. Low-regret actions are relatively low cost and provide relatively large benefits under predicted future climates. Win-win actions contribute to adaptation whilst also having other social, economic and environmental policy benefits, including those relating to mitigation.	• Regret • No-regret • Low-regret • Win-win	Check box (single choice)	[8]
Flexibility	-	Potential for adjustments to different climate scenarios and socioeconomic developments. The adaptation options allowed easy adjustments and incremental implementation if conditions changed or if changes are different from those expected today. In this sense, adjustable options should be able to be adapted to different climate scenarios as well as socio-economic development trends. (Example for measurement: Does the proposed options take sufficient consideration of the uncertainty aspect of climate change? Do the options remain useful under less or unexpected manifestations of climate change? Can the options easily be adapted if conditions are changing or different? This information can be obtained through expert and stakeholder judgement.	* High * Middle * Low	Check box (single choice)	[8]
Time horizon	-	It refers to the requierd time to start being effective the option	* Short (<5 y), * Medium (5 to 10y), * Long term (>10)	Years	
Implementing-time	-	It refers to the requierd time to implement the option	*Enduring *Long >10 *Medium >5 *Short <2	Years	
Effective life-time or Sustainability	-	Time span during which the adaptation practice keeps on being effective, after having been implemented. The likelihood that benefits/outcomes of the adaptation options/ adaptation process will continue for an extended period of time after the project completion, as well as the ability of stakeholders to continue the adaptation processes beyond project lifetimes. Sustainable development is expected to minimise the threats posed by the impacts of climate change and to capitalise on the potential opportunities presented by it, and bring benefits in terms of alleviating pre-existing problems (no-regret).	*Enduring *Long >100 *Medium >30 *Short <30	Years	[1] [8]

Dimension	Sub dimension	Description	Variables	Units	Reference: literature
Side effects. It refers to co-lateral effects. The side effects are positive and negative. Negative (also referred to as maladaptation): are indirect, negative outcomes set off by the measures outside of the target. Positive (effects): are additional beneficial outcomes delivered by the measures but not aimed at in the first place	Economic	Effects on innovation and competitive advantage; effect on employment	* Positive * Negative * No effects	Check box (single choice)	[8]
	Environmental	Synergies with mitigation, positive environmental effects (biological, diversity, …), avoiding maladaptation	* Positive * Negative * No effects	Check box (single choice)	[8]
	Social	Distributional impacts (different social or economic groups)	* Positive * Negative * No effects	Check box (single choice)	[8]
	Health	Effects on health	* Positive * Negative * No effects	Check box (single choice)	

Table 7. Organisation

Dimension	Description	Variables	Units	Reference: literature
Responsible party	Stakeholder responsible for implementation- It relates to the Governance and institutional needs.	* National government * Regional administration * Municipality * Company * Household/individual * Water board/water catchment management organisation	Check box (single choice)	[36] [6]
Primary beneficiary Group	It refers to the social impact of the measure. It can be exclusive (attentión placed to vulnerable group or groups so only one section of the population) or inclusive (all citizens)	* Potential diversity strands - age, disability/special needs, ethnicity (related to language as a barrier) *Demographic dependency (Children and youth) *Senior citizens (Elderly) *Disabled/ special needs (physical, mental or sensory disabilities) *Immigrants *Single-parent families *Households with one member *Unemployed *Beneficiaries of minimum incomes (insertion) *Households with less than half the national average income *Poor people / Homeless *People with (or without) studies (primary, secondary, tertiary studies) *People with health problems	%	[**¡Error! Marcador no definido.**]
Feasibility	To what extent is the option sensitive to barriers preventing the implementation of the option? (e.g. technical, political, climatic, spatial)	* Highly sensitive * Moderately sensitive * Slightly sensitive * Not sensitive/no barriers known	Check box (single choice)	
Requirements	Gives an idea of the requirement for the implementation of the measure. The required information will be yes or no in the following requirements: spatial requirements (gives an idea of the land requirement for the implementation of the measure: depending on the land cover characteristics or the density of an urban area, it is more complex or less to implement a measure with high or low space requirement); subsurface depth requirements (it refers to the subsurface depth required for the measured to be effective: those could be express as requirements or as barriers for the implementation of technical options); geomorphologic conditions: slope of the terrain (sloping area, flat area on high ground with deeper groundwater levels, flat area on low ground with shallow groundwater levels), soil type (sand, peat, clay, bed rock); micro-scale climatic conditions: solar radiation, temperature, precipitation pattern; human resources (qualified human resources required in terms the expected expertise and profile, during the implementation).	* Spatial requirements * Subsurface depth requirements * Geomorphologic conditions: slope of the terrain, soil type * Micro-scale climatic conditions: solar radiation, temperature, precipitation pattern * Human resources: qualified human resources required in terms the expected expertise and profile (during the implementation).	Check box (multiple category choice)	[9]
Maintenance	To what extent is maintenance required to maintain the effectiveness of the option (once this has been implemented. i.e. how onerous is the maintenance requirement…)	Degree of intensity: * High * Moderate * Low	Check box (single choice)	

Dimension	Description	Variables	Units	Reference: literature
Acceptability	Is the option accepted by the public/is it politically and socially acceptable?	* Stakeholder/political acceptance: widely accepted, largely accepted, little acceptance, unaccepted * Social/citizen acceptance: widely accepted, largely accepted, little acceptance, unaccepted		[49]
Monitoring: (periodic vulnerability assessments)	It refers to monitoring of adaptation measures implementation. The objective here is to quantify the outcome of an adaptation option on a system's sensitivity or adaptive capacity, and thus its vulnerability.	It is possible to distinguish between adaptation level to be monitored and the time interval: * Project level (Every 3-5 years) * Adaptation program or strategy (Every 5-10 years)	Years	[50]

Table 8.Cost-efficiency

Dimension	Description	Variables	Units	Reference: literature
Investment cost	Additional cost relative to the "base case" (the situation in which the adaptation measure has not been installed). Provide the year that applies cost data, currency exchange rates	1_Direct cost: * Investment expenditure: adaptation equipment expenditure, installation expenditure * Annual operating and maintenance costs: energy costs, materials and services costs, labour costs. Fixed operating/maintenance costs * Costs of administrative implementation of adaptation measures.	Numeric: * € And if that is not available the option to provide a qualitative statement: * No extra costs * Moderate extra costs * High extra cost	[28] [**¡Error! Marcador no efinido.**] [51]
		2_Indirect or external costs: * environmental and social costs, time saved, ...	Euros	[**¡Error! Marcador no efinido.**]
Benefit	Separating ex-ante (base case) and post-ante adaptation measures. Benefits of an adaptation intervention should include the avoided damages from climate change impacts and co-benefits, where relevant. If there is no market for the goods or services provided by the adaptation activity, benefits can be estimated in indirect ways through nonmarket-based approaches, such as contingent evaluation	Economic: monetary benefits resulting from the activity developed. Net Economic Benefits	Euros	[30][**¡Error! Marcador no efinido.**] [**¡Error! Marcador no definido.**]
		Environmental: positive side-effects on environment (for example: water savings)	Euros	[30] [3433] [**¡Error! Marcador o definido.**]
		Social: positive side-effects on society (for example: cohesion, equity, quality of life)	Euros	[30] [3433] [**¡Error! Marcador o definido.**]
		Health: benefits associated to reduced stress, mortality or morbidity	Euros	
The relationship between cost and benefit	Cost-benefit analysis. Economic viability of adaptation measures in terms of their costs and benefits ratio. Adaptation measures are assessed based on whether they can reach their objectives in the most efficient way in economic terms (e.g. they achieve objectives at least cost) and have a balanced cost/benefits ratio. The benefits of adaptation measures are compared to costs and effort. A CBA is basically comparing costs and benefits of an intervention over time	* Net present value (NPV): benefits minus costs calculated at their present value, i.e. using a discount rate for future benefits and costs (it is important to point the discount rate selection). * The benefit-cost ratio (BCR) is the ratio of benefits to costs. * The internal rate of return (IRR): is the discount rate at which the NPV becomes zero * The willingness to pay (WTP) * or the willingness to accept (WTA)	Check box (single choice)	[30] [32] [**¡Error! Marcador no efinido.**] [33] [3433] [**¡Error! Marcador no definido.**]
	Cost-effectiveness analysis. It determines how a well-defined objective can be achieved in the most cost-efficient way. Costs need to be quantified in monetary terms to conduct a CEA. The procedure is identical to the cost assessment used in a CBA. It is not possible to assign a monetary value to benefits. Therefore, the unit in which benefits are measured has to be carefully defined.	* Cost-Benefit-Ratio (CBR) * Benefit-Cost-Ration (BCR)	Check box (single choice)	[30] [32] [33]
	Multi-criteria analysis. It consist on a qualitative assessment of criteria (such as feasibility, cost effectiveness, co-benefits, ease of implementation, acceptability to local population and resources required, …)	* Ranking of the measures evaluated according to their scores: First place, second, third, fourth, fifth, sixth, seventh, eighth, ninth, tenth	Check box (single choice)	[33] [**¡Error! Marcador no efinido.**]
Co-benefit	Describes if a measure has benefits in a single-hazard or more hazards (multi-hazard)	* Single hazard * Multi-hazard	Check box (single choice)	[9]

Dimension	Description	Variables	Units	Reference: literature
Uncertainty	Of evaluated costs and benefits. Future prices, wages and inflation need to be referenced. Use a data quality rating system	• An estimate based on a large amount of information fully representative of the situation and for which all background assumptions are known. • An estimate based on a significant amount of information representative of most situations and for which most of the background assumptions are known. • An estimate based on a limited amount of information representative of some situations and for which background assumptions are limited. • An estimate based on an engineering calculation derived from a very limited amount of information representative of only one or two situations and for which few of the background assumptions are known. • An estimate based on an engineering judgement derived only from assumptions.	Check box (single choice)	[28] [**¡Error! Marcador no efinido.**]
Combinability	To what extend can the measure be integrated and combined with other adaptation measures? This information can be obtained through expert and stakeholder judgement.	• Measure has little possibility for integration • Measure can be combined and complement but to a limited extent • Measure can complement / combine with certain measures in water sector • Can complement / combine with a variety of measures in water sector • Can complement / combine with other measures of different sectors	Check box (single choice)	[9] [35] [36] [37]

7. References

1 IPCC (2014). Climate change 2014: Impacts, Adaptation and Vulnerability. Chapter 14: Adaptation needs and options (http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap14_FINAL.pdf)

2 ESPON CLIMATE - Climate Change and Territorial Effects on Regions and Local Economies in Europe (2011) (http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/climate.html)

3 EEA (2012). Urban Adaptation to Climate Change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA, Report No 2/2012 ISSN 978-92-9213-308-5, Copenhagen; Climate Change and Territorial Effects on Regions and Local Economies

4 Pötz, H. & Bleuzé, P. (2012). URBAN GREEN-BLUE GRIDS FOR SUSTAINABLE AND DYNAMIC CITIES. Publisher coop for life, Delft, ISBN 978-90-818804-0-4 (http://www.urbangreenbluegrids.com/design-tool/)

5 Niang-Diop, I. and Bosch, H. (2005). Formulating an Adaptation Strategy. In: Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures by Burton, I., Malone, E.L., Huq, S., Lim, B., Cambridge University Press, Cambridge, 183-204.

6 ClimWatAdapt, Climate Adaptation – modelling water scenarios and sectoral impacts. Inventory of measures: http://climwatadapt.eu/inventoryofmeasures

7 Flörke, M., Wimmer, F., Laaser, C., Vidaurre, R., Tröltzsch, J., Dworak, T., Stein, U., Marinova, N., Jaspers, F., Ludwig, F., Swart, R., Giupponi,C., Bosello, F., Mysiak, J. (2011). Final Report. Climate Adaptation – modelling water scenarios and sectoral impacts Contract N° DG ENV.D.2/SER/2009/0034

8 BASE project. Bottom-Up Climate Adaptation Strategies Towards a Sustainable Europe. Deliverable BASE D2.3 (http://base-adaptation.eu/)

9 Voskamp, I. M., & Van de Ven, F. H. M. (2014). Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Building and Environment, 83, 159–167. doi:10.1016/j.buildenv.2014.07.018

10 A.F. Speak; J.J. Rothwell; S.J. Lindley; C.L. Smith. (2013). Rainwater runoff retention on an aged intensive green roof. Science of the Total Environment, 461-462 (2013) 28-38. doi:10.1016/j.scitotenv.2013.04.085

11 Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning, 97(3), 147–155. doi:10.1016/j.landurbplan.2010.05.006

12 Schoetter, R., Grawe, D., Hoffmann, P., Kirschner, P., Grätz, A., & Schlünzen, K. H. (2013). Impact of local adaptation measures and regional climate change on perceived temperature. Meteorologische Zeitschrift, 22(2), 117–130. doi:10.1127/0941-2948/2013/0381

13 Bosch, P. (2014). Guideline Effectiveness of Adaptation Measures : Common Units, (November).

14 Perini, K., Ottelé, M., Fraaij, A. L. a., Haas, E. M., & Raiteri, R. (2011). Vertical greening systems and the effect on air flow and temperature on the building envelope. Building and Environment, 46(11), 2287–2294. doi:10.1016/j.buildenv.2011.05.009

15 Müller,N., Kuttler, W.& Barlag, A.B. (2013). Counteracting urban climate change: adaptation measures and their effect on thermal confort Theor Appl Climatol DOI 10.1007/s00704-013-0890-4

16 Perini, K., & Rosasco, P. (2013). Cost–benefit analysis for green façades and living wall systems. Building and Environment, 70, 110–121. doi:10.1016/j.buildenv.2013.08.012

17 Van Hooff, T., Blocken, B., Hensen, J. L. M., & Timmermans, H. J. P. (2015). Reprint of: On the predicted effectiveness of climate adaptation measures for residential buildings. Building and Environment, 83, 142–158. doi:10.1016/j.buildenv.2014.10.006

18 Sušnik, J., Strehl, C., Postmes, L. a., Vamvakeridou-Lyroudia, L. S., Savić, D. a., Kapelan, Z., & Mälzer, H.-J. (2014). Assessment of the Effectiveness of a Risk-reduction Measure on Pluvial Flooding and Economic Loss in Eindhoven, the Netherlands. Procedia Engineering, 70, 1619–1628. doi:10.1016/j.proeng.2014.02.179

19 Liu, W., Chen, W., & Peng, C. (2014). Assessing the effectiveness of green infrastructures on urban flooding reduction: A community scale study. Ecological Modelling, 291, 6–14. doi:10.1016/j.ecolmodel.2014.07.012

20 Chapman, C., Horner, R.R. (2010). Performance as-sessment of a street-drainage bioretention sys-tem. *Water Environment Research* 82, 109–119.

21 Qin, H., Li, Z., & Fu, G. (2013). The effects of low impact development on urban flooding under different rainfall characteristics. Journal of Environmental Management, 129, 577–85. doi:10.1016/j.jenvman.2013.08.026

22 Alfredo et al 2009

23 Dreelin, E. a, Fowler, L., & Ronald Carroll, C. (2006). A test of porous pavement effectiveness on clay soils during natural storm events. Water Research, 40(4), 799–805. doi:10.1016/j.watres.2005.12.002

24 RAMSES project. Reconciling Adaptation, Mitigation and Sustainable Development for cities. Deliverable D2.4 (http://www.ramses-cities.eu/)

25 Swart, R.J., Fons, J., Geertsema, W., Hove, L.W.A. van, Jacobs, C.M.J. (2012). Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA. Technical Report 01/2012)-178 p.

26 K-EGOKITZEN: Climate Change. Impacts and Adaptation. Basque Government, 2007-2012. Leadership: Labein-Tecnalia, 14 research groups, including 5 University departments (UPV/EHU) and 2 Technological Center: AZTI, NEIKER. ETORTEK project

27 AEA - Review of international exposure, sensitivity and adaptive capacity in adaptation indicators

28 Bosch, P. & Pásztor, A. (2012). Guideline Costs of Adaptation Measures. KfC report number: 107/2013. Climate Proof Cities consortium.

29 Hurd, B. & Rouhi-Rad, M. (2012). Estimating Economic Effects of Changes in 2 Climate and Water Availability. Climatic Change, An Interdisciplinary, International Journal Devoted to the Description,Causes and Implications of Climatic Change ISSN 0165-0009. Climatic Change DOI 10.1007/s10584-012-0636-9

30 UNFCCC (2011). Assessing the costs and benefits of adaptation options, an overview of approaches. The Nairobi Work Programme on impacts, Vulnerability and Adaptation to Climate Change. ISBN 92-9219-085-7

31 BASE project. Bottom-Up Climate Adaptation Strategies Towards a Sustainable Europe. Deliverable BASE D2.3 (http://base-adaptation.eu/)

32 GSF (Global Climate Chance Alliance Support Facility) (2011). Costing, assessing and selecting, adaptation and mitigation, options and measures. Training workshop on mainstreaming climate change: module 6. Broomfield, CO: MWH.

33 Noleppa (2013). Economic approaches for assessing climate change adaptation options under uncertainty. Excel tools for Cost-Benefit and Multi-Criteria Analysis. Deutsche Gesellschaft für, Internationale Zusammenarbeit (GIZ) GmbH. Eschborn.

34 Máñez, M., & Cerdà, A. (2014): Prioritisation Method for Adaptation Measures to Climate Change in the Water Sector, CSC Report 18, Climate Service Center, Germany.

35 Deckers, P., Fournier, M., Boeckx, L., Vanneuville, W. (2013). Climate-check of present and planned measures on the Meuse basin. WP1 report -Action 8. AMICE Project, Adaptation of the Meuse to the Impacts of Climate Evolutions is an INTERREG IVB North West Europe Project (number 074C).

36 Flörke, M., Wimmer, F., Laaser, C., Vidaurre, R., Tröltzsch, J., Dworak, T., Stein, U., Marinova, N., Jaspers, F., Ludwig, F., Swart, R., Giupponi,C., Bosello, F., Mysiak, J. (2011). Final Report. Climate Adaptation – modelling water scenarios and sectoral impacts Contract N° DG ENV.D.2/SER/2009/0034

37 ClimWatAdapt, Climate Adaptation – modelling water scenarios and sectoral impacts. Inventory of measures: http://climwatadapt.eu/inventoryofmeasures -Annex 11

38 IPCC (2012): Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp. Annex II (http://ipcc-wg2.gov/SREX/report/full-report/)

39 Urban green-blue Grids for sustainable and resilient cities (http://www.urbangreenbluegrids.com/design-tool/)

40 GRaBS project. Green and blue space. Adaptation for urban areas. (http://www.grabs-eu.org/ , http://www.ppgis.manchester.ac.uk/grabs/tool.html)

41 ADAM project. Adaptation and mitigation strategies: supporting European climate policy (http://www.tyndall.ac.uk/adamproject/about)

42 Project "Adaptation Strategies for European Cities", 2012 (http://climate-adapt.eea.europa.eu/documents/18/11155975/Adaptation_Strategies_for_European_Cities_Final_Report.pdf)

43 European Comission (2013a). Adapting infrastructure to climate change, EC SWD(2013) 137 (http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_137_en.pdf)

44 European Comission (2013b). Green Infrastructure (GI) - Enhancing Europe's Natural Capital, EC SWD(2013) 155 (http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructures/1_EN_ACT_part1_v5.pdf)

45 HORIZON 2020 – WORK PROGRAMME 2014-2015 (General Annexes) (http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)

46 Olazabal, M., Herranz, K., Abajo, B., Gutierrez, L., García, G., Feliú, E., Mendizábal, M., Proy, R. & Izaola, B. (2009). Ordenación del territorio y Planificación urbana (Anexos). CAMBIO CLIMATICO: IMPACTO Y ADAPTACION. Programa: ETORTEK ejercicio 2009. Ayudas a la Investigación Estratégica

47 Tapia, C., Abajo, B., Feliu, E., Fernández, J.G., Pa-dró, A., Castaño, J. (2015). ANÁLISIS DE VULNERABILIDAD ANTE EL CAMBIO CLIMÁTICO EN EL MUNICIPIO DE MADRID. Di-rección General de Sostenibilidad y Control Ambiental Área de Gobierno de Medio Am-biente y Movilidad AYUNTAMIENTO DE MADRID, Madrid.

48 EEA (2012). Report No 2. Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. ISSN 1725-9177 (http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change)

49 Willows, R.I. and Connell, R.K. (eds). 2003. Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical report, UKCIP, Oxford (www.ukcip.org.uk/wordpress/wp-content/PDFs/Risk.pdf)

50 Vulnerability Sourcebook, Concept and guidelines for standardised, 2014.

51 ECONADPT (2015). The Costs and Benefits of Adaptation: Results from the ECONADAPT Project. Editor Watkiss, P. Published by the ECONADAPT consortium.