Subgroup: Water

Other Subgroups: Health, Urban

Case-study: Tagus Water District

(UPM & BC3)

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Purpose of this document: "The Case Studies Living Document (CSLD) will be the document that each case study leader will use to share the information that (i) characterize and give context to its case study, (ii) the goals within BASE, (iii) the methods used and mainly (iv) a synthesis of the results that that case study is providing to BASE project. This will allow the CS leader to understand how its own case is going (having a good overview), but also (v) will allow the sub-group to which the case study belong to know what is happening and what can be done (mainly on synergies and so on) as well as to (vi) WP4 & 5 coordinators to use that information to report (including each WP task leaders). These living documents will also (vii) allow WP6 & 7 partner to know the information."

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General Case Study Description Location

The case study is focused on climate adaptation to water shortages and health effects in the Tagus Water District of Spain, predominantly in urban municipalities: Madrid metropolitan area that comprises 22 municipalities.

GPS: N 40°26′ / E 3°41′ (Madrid) Area: 78.467 km^2 (Tagus river water district)

A. Location

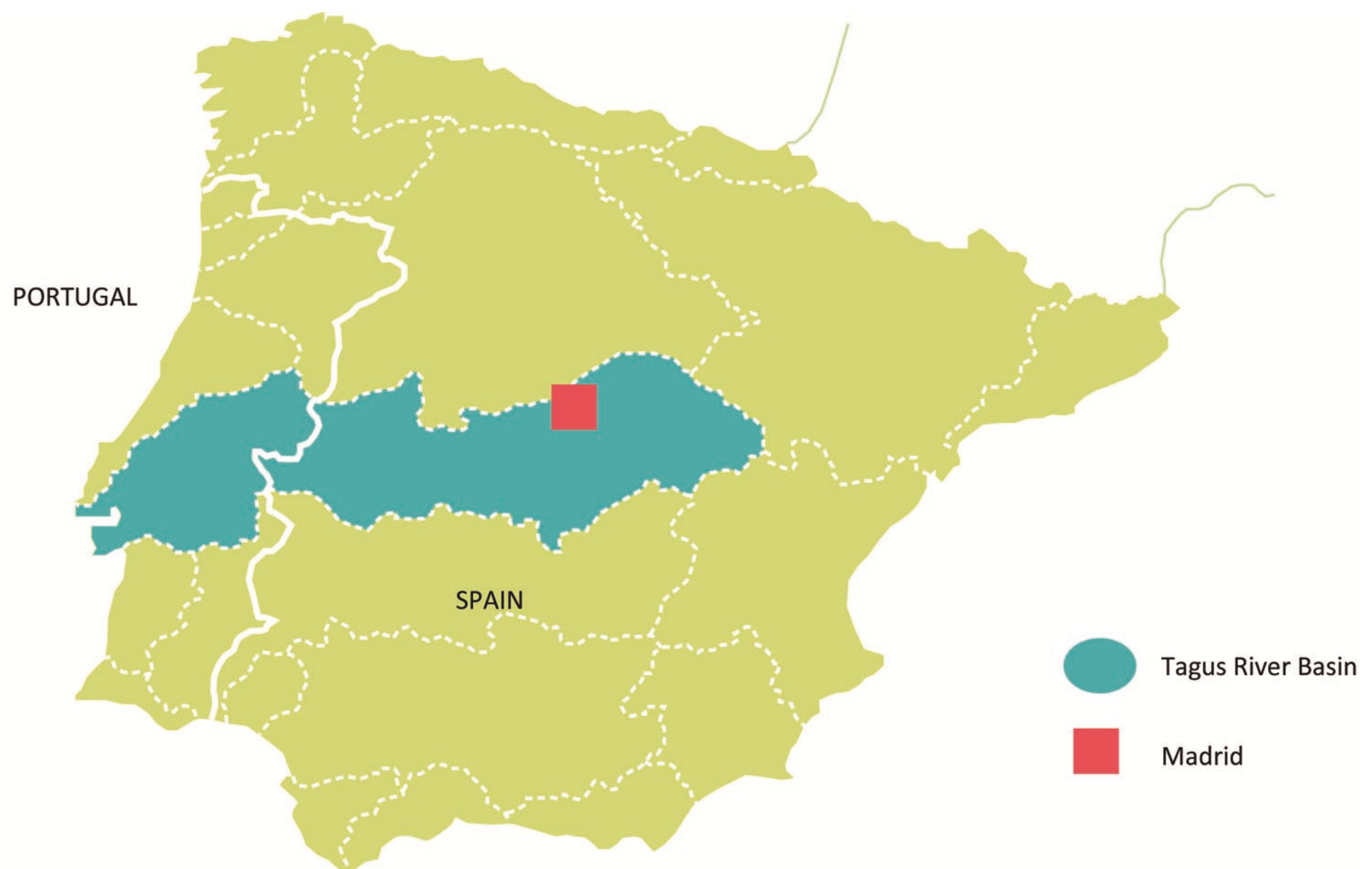


Figure 1 The case study of the Tagus Water District in Spain: Water, health and urban areas

B. Case Study Summary

Here we provide a framework to define alternative policy choices for adapting water and health in the Tagus Water District, considering climate change projections. The case study focuses on climate

adaptation to water shortages and health effects in the Tagus Water District of Spain, predominantly in urban municipalities: Madrid metropolitan area that comprises 22 municipalities. The aim is to identify the co-benefits of the adaptation strategies in different sectors. The case study is structured in three scales of analysis: local, regional and national, involving stakeholders, experts and citizens.

The design the adaptation strategies organized around the idea that understanding resilience, policy trade-offs, and flexible mechanisms.

We analyse adaptation by a number of approaches: modelling, a range of participatory approaches and statistical methods.

The case study will develop a methodological framework to assess costs and benefits of cross-sectoral adaptation strategies to reduce the impacts of heat waves in the area of Madrid. The analysis will focus on the co-benefits of a set of adaptation measures in different sectors. The area of Madrid has been chosen as a case study due to its multiple vulnerabilities due to climate change, its large size and population, its drought-prone climate and its use of trans-boundary water. The study will identify measures with co-benefits specifically on water and health and assess their costs and benefits.

Identifying and calculating co-benefits is one of the most effective ways to prioritize adaptation measures, and this can only be done through participatory approaches. In this sense, the case study will use a participatory process to get information from the stakeholders about the complexity of the system, about their feedbacks and main drivers, responding to the questions of: What are the impacts of heat waves in the city of Madrid? What are the potential adaptation measures? This will be done through the method Fuzzy Cognitive Mapping (FCM) which allows modelling the system in a semi-quantitative way and simulating policy options (running different policy scenarios). This information used to feed the cost-benefit analysis (CBA) of a selection of adaptation measures also obtained from the process of interviews to the stakeholders. Additionally and also with the intention to feed the CBA, a health impact assessment (HIA) based on different climate scenarios will be performed. This way the case study will fulfil 5 specific objectives: (1) study direct and indirect impacts of heat waves on health in the city of Madrid and outskirts; (2) establish synergies (co-benefits) and tradeoffs between sectors; (3) robust understanding of system complexity (using of causal networks informed public authorities and researchers), (4) economic valuation (benefits and costs) of selected measures; and (5) provide information to local policy makers.

The case study builds on previous knowledge and proposes a four steps method involving the main stakeholders at different scales. The first step involves National Regional and Local Administration decision makers with key actors of Water, Energy and Agriculture sectors in a workshop to exchange information on vulnerabilities and identify adaptation pathways. The second step —carried out through a Fuzzy Cognitive Mapping method, with twenty five experts— looks for a semi quantitative weighting of measures. In the third step a cost and benefit analysis is performed an adaption measures are evaluated and compared. Finally the case study will explore the incentives and barriers of the civil population to implement the adaptation strategies. This is based on a panel survey with the aim of defining:

- How do citizens perceive climate adaptation and the need for climate adaptation actions? What is their risk perception?
- What climate adaptation actions they know (if any)? And what are the costs? Are there any experienced benefits?
- Do citizens experience any conflict between climate adaptation policies and other policies (e.g. urban planning)?

C. Context

(a) Water resources in the Tagus Water District

Impacts on water resources are the main focus of the case study. The combination of increasing temperature and decreasing precipitation cause a reduction of inputs and a modification of the water demand.

Current water resources in the Tagus Water District are scarce and their current level of use is very high. Adaptation measures may include making the most efficient use of supply sources currently available and increasing the availability, if needed, to adapt to future climate and socioeconomic scenarios.

Water is essential for ecosystems. A high number of the protected natural areas in the study area are placed in the riverbanks. Climate change will reduce biodiversity in those ecosystems and their byogeochemical cycles will be altered. In addition to the direct effects of climate change on natural areas the increasing demand of water for other uses can also have a strong impact on ecosystems.

(b) Urban water use

While current resources ensure supply to urban areas, climate change poses a threat to the maintenance of this level of assurance in the future, therefore adaptation to climate change is essential. Adaptation measures should include rationalization of water use, increasing efficiency and reducing consumption.

The relative importance of water resources on social activities is higher in the Tagus Water District than in other regions because it serves a population of more than 7 million people, therefore the implementation of adaptation measures will necessarily affect other water-dependent sectors.

Urban areas have undergone unprecedented social, economic and environmental transformations, in many cases not foreseen by planners. Urban planning will have to take into account adaptation measures to provide a sound framework to develop the various economic sectors. Building methods must reduce the use of resources, including water, energy and transportation, not only as adaptation but also as mitigation measures.

(c) An overview of health climate impacts in Spain and Madrid

Climate change can have an effect on health by intensification of extreme events as heat waves or drought periods, and by increasing the rate of transmission of certain types of diseases. The alteration of the hydrological regime of rivers may also affect health by altering the vectors of transmission of infectious diseases. Recent studies relate mental health problems with extreme events.

The report 'Global Change in Spain, 2020/2050: Climate Change and Health' (ISTAS, 2012) covers the main climatic impacts and their health effect specifically relevant for the Spanish region given the experienced and expected impacts. As a result the following impacts have been considered significant:

Table 1 Climate Change potential effects in Spain and related health risks. Source: (ISTAS, 2012)

POTENTIAL EFFECTS OF CLIMATE CHANGE IN SPAIN	ASSOCIATED HEALTH RISKS
EXTREME EVENTS	
Increased frequency, duration and intensity of heat waves	Increases in heat related deaths, especially from cardiovascular and respiratory problems, with particular effects for the elderly, the infirm and the weak.
Possibility of significant cold snaps	Increased cold related deaths, from cardiovascular and respiratory problems (though to a lesser extent than from heat), affecting particularly the elderly, the infirm and the week, including children and young people.
More frequent droughts	Impact on mental health Increases in outbreaks of waterborne diseases Increases in outbreaks of food-related diseases Greater risk of forest fires (respiratory and cardiovascular problems) Problems in agricultural production: higher prices and shortages of basic foodstuffs in extreme cases
A tendency for more episodes of torrential rain and subsequent flooding	Direct effects: drownings, injuries, diarrhoea, vector-borne diseases, respiratory infections, skin and eye infections, mental health problems Damage to supply systems (deterioration in the quality of drinking water) and sewerage systems, crops, housing, living conditions and the mobility of the population Damage to health care system provisions and amenities
WATER AND FOODSTUFFS	
Contamination of water supplies and water used for recreational purposes Reduction in net water offtakes and increased demand	Increases in outbreaks of seasonal waterborne diseases Increased exposure to biological and chemical pollutants
Impact on the distribution, seasonality and transmission of food-related diseases	Increases in food-related diseases
Increases in the transporting and dissemination of human agents from inland areas towards coasts and estuaries (as a result of storms and flooding) Changes in environmental and oceanographic variables (temperature and salinity) Flourishing of toxic algae and bio-accumulation in marine products for	Contamination of marine products (by toxins and marine pathogens and by human and animal pollutants) Food poisoning related to the conservation of marine products

human consumption	
VECTORS	
Changes in vector capacity Appearance of potential breeding sites (after extreme rainfall)	Changes in the incidence and distribution of vector-borne diseases
ATMOSPHERIC POLLUTION	
Increased concentrations of some pollutants in the ambient air, which are especially significant in the cases of suspended particles and ozone	Increases in hospital admissions: respiratory diseases, cardiovascular diseases * Increases in the death rate * *Future regulations to control ozone and PM2.5 particles are highly influential here
POLLEN	
Increases in the production of pollen and fungal spores Longer pollen seasons Potential changes in the geographical distribution of species that produce allergenic pollen	A worsening in respiratory and allergic problems such as allergic rhinitis and asthma
UV RADIATION	
Increased exposure to UV radiation	Cancer and other skin diseases, cataracts, eye damage Effects on immunological systems

In particular, this report highlights that heat waves in Spain will have an impact on mortality, especially cardiovascular and respiratory and significantly in old, sick or weaker people. Also that droughts, will impact mental health and water and food borne diseases. As indirect impacts, a higher risk of forest fires will increase cardiovascular and respiratory problems and that agrarian productivity problems may lead to an insufficiency of basic food provision in extreme cases.

The last report from the Spanish Government developed by the Ministry of Health, Social Services and Equity (Spanish Government, 2013) highlights that the main climate change effects on health in Spain are related to extreme temperatures, water quality, air quality and vector-borne diseases. The effects of climate change on health can have multiple paths as illustrated by De Sario et al. (2013) (see Figure):

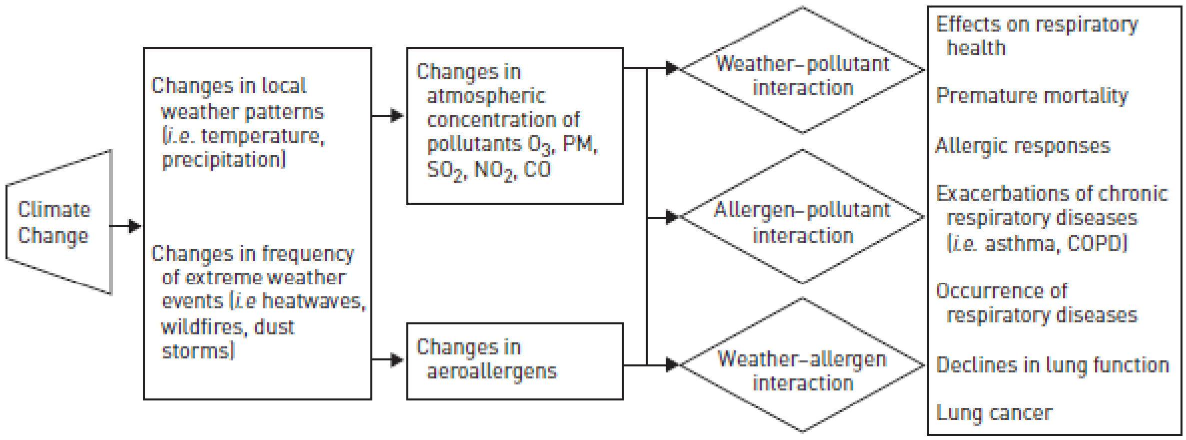


Figure 2 Climate change: its influence on extreme weather events, air pollution and aeroallergens, and effects on respiratory health. PM: particulate matter; COPD: chronic obstructive pulmonary disease. Source: De Sario et al. (2013)

As an example, high temperatures in Europe and the Mediterranean are accompanied by African South wind and dust storms (De Sario et al., 2013), and this also applies to Madrid (Garcia-Herrera et al., 2005). This increases the particulate matter. Studies in Madrid show that an increase of PM10 only on dust days has significant effects on all-cause, cardiovascular and respiratory mortality (Jiménez et al., 2010).

Regarding the allergies, according to the Global Change report (ISTAS, 2012), it is significant a seasonal peak of asthma-caused hospitalizations (between May and June) in the Spanish regions located at the heart of the peninsula such as Guadalajara, Madrid, Toledo, Valladolid, Salamanca and Badajoz. The quick transitions from cold to warm temperatures, rain scarcity and the coincidence with the pollen season, are the cause of the increase in pollen induced allergies.

Not many others studies have been developed in the region of Madrid though regarding other types of impacts (De Sario et al., 2013), to our knowledge.

Among these health climate impacts, we pay a particular attention to the temperature-health relation in Madrid in the next section. To our knowledge, there is no studies that values the climate-health relation in economic terms.

D. Brief General Information on Climate Change and related issues

(Máx 2000 words) Please state which is the European climate zone of the case study and insert any information regarding the current available information regarding the case-study, namely expected impacts, scenarios.

(a) Observed climate in the Tagus Water District

Climate in the Iberian Peninsula is Mediterranean with hot and dry summers and cool winters. There is great variation in temperature and average rainfall due to the large differences in the orography. In most of the territory it rains less than 700 mm per year, with drier areas where it rains less than 500 mm annually. In the mountains, however, the rains increase rapidly with altitude and can exceed 1,500 mm annually. The wettest seasons are spring and fall, since they reach the maritime polar air mass which brings the polar front. The Summer is dry because it is dominated by the Azores anticyclone. The winter is drier than the spring and fall because of the area are installed thermal anticyclones also cause persistent fog.

Temperatures show a very sharp gradient following a similar pattern of rainfall. The hottest month is August and January the coldest. Summer becomes hot, so are long and cold winters, warm summers and spring and autumn are short seasons and irregular but very marked.

Climate in the Madrid region has some peculiarities due to the large proportion of urbanized territory. The region has the highest population density of the Spanish territory reaching 749.5 hab/Km2 (MARM 2010), three times higher than the next, being the 12% of the land occupied by cities of more than 100,000 habitants (MMA 2005).

Typically temperatures are higher in cities than on the outskirts and this difference increases on stable periods for the presence of the anticyclone, giving rise to the phenomenon called urban heat island, an atmospheric situation that occurs in big cities and involves rapid increase in temperature form the outskirts to the city centre, where buildings and asphalt off the heat accumulated during the day.

The urban heat island effect has been widely studied in Madrid Region (e.g. Bejarano, 2002 o Fernández García y Rasilla Álvarez, 2008) and shows a decreasing thermal gradient between the centre and the periphery in the city with smaller heat islands in the surrounding municipalities such as Alcorcón, Alcobendas, Getafe, etc. (Ayuntamiento de Madrid, 2008).

Figure 1 shows the rising of temperatures in the last 10 years in the Madrid Region. In urban areas part of the temperature increase might be due to the urban heat island and part due to the global climate change.

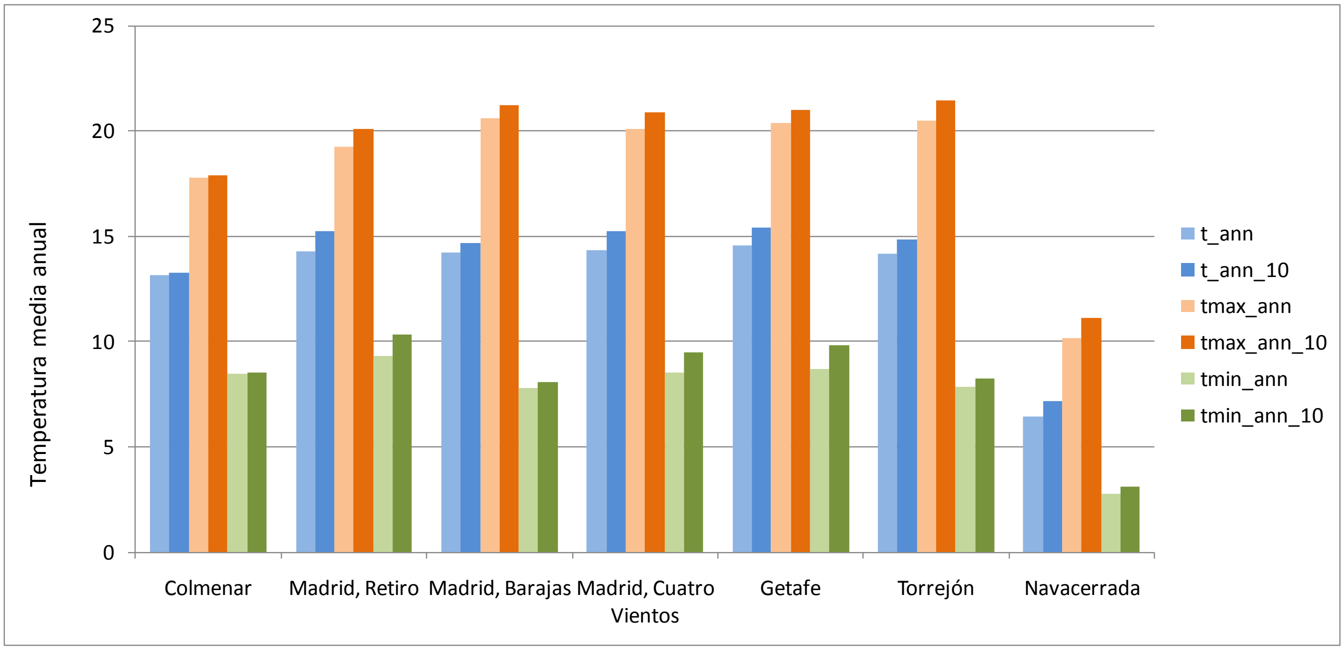


Figure 3 Mean, maximum and minimum temperatures during the entire period of climate data compared to the past ten years in several stations of the Madrid Region

One of the most outstanding characteristics of the Madrid climate is the irregularity of the interannual rainfall, as shown on Figure 5.

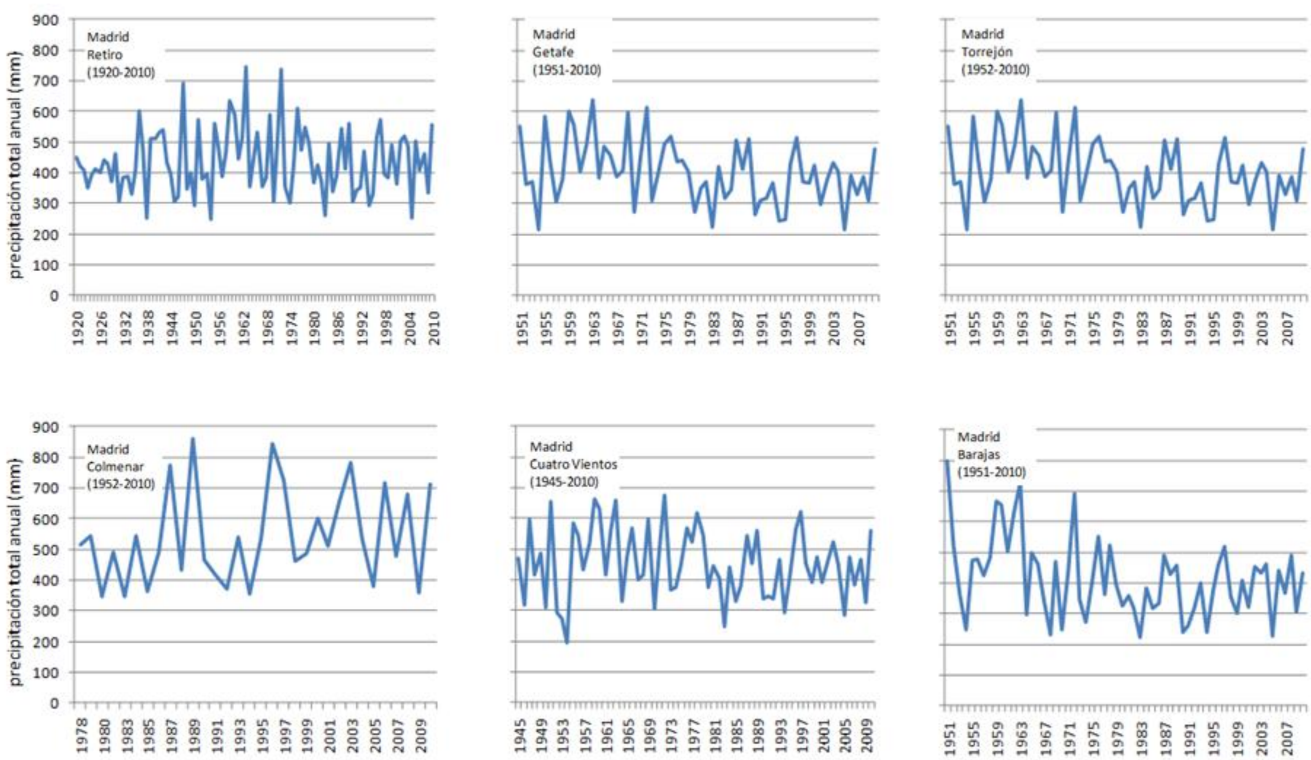


Figure 4 Annual rainfall in different stations in Madrid Region. (Source: Garrote, Iglesias, 2012)

Though it is difficult to determine the trend, but data of the last 30 years might suggest a slight decrease in rainfall. There has been in this period an increase of evapotranspiration with consequences in the quality and availability of water resources, with a high social impact due in general to the concentration of population and the seasonal population growth in some areas, and to the difficulty of controlling water use and to cultural barriers.

Future climate will depend partly on the concentration of greenhouse gases, which will be basically conditioned by the population growth, the economic growth and the energy technology that determines the emissions caused by human activities

(b) Social pressures on water resources

Irrigated agriculture is the main consumer of water in the Mediterranean (Figure x). The evolution of irrigation in all Mediterranean countries has been remarkable over the last half century, although northern and southern Mediterranean countries differ in relation to the rate of expanding their irrigated land and irrigation technologies used (Garrido and Iglesias, 2006). In general, there is little development of new irrigation areas and the investments focus on rehabilitation of existing schemes, and improvement of irrigation technologies. But, nevertheless there is a rapid increase in the water demands in all countries as a result of the increase of economic and social activities together with the increasing demand for tourism and for the ecosystems.

Currently there is an increasing pressure on water resources in Mediterranean countries, derived from population dynamics, upgraded standard of living, economic and social development, and the use of water consuming technologies. Population growth in many southern Mediterranean countries is the major factor affecting water resources, reducing the water availability per capita. Urbanization increases urban demands which are of high-priority and intensifies conflicts among users. Tourist population in the Mediterranean is very significant, and tourist water consumption is about three times higher than local demands (EEA, 2000). The number of international tourist arrivals increases every year; in Spain, Greece, and France; the number exceeds total countries' population by about one third (World Tourist Organization, 2005). Tourist consumption is highly seasonal, but the industry increases permanent water demand for facilities and leisure structures. Particularly Spain is experiencing a tourist and second-home boom all across the Mediterranean coast and together with the 275 golf courses (75 more are on project only along the Mediterranean coast), represent a demand increase of about 30 million m3. This demand is a small fraction of agricultural demand at the country or regional level (for example in Cyprus tourist demand represents 5 percent of total contrasting with about 70 percent of agricultural demand), but at the local level in key tourist destinations it is the main demand (for example in Majorca, Spain; Essex et al., 2004).

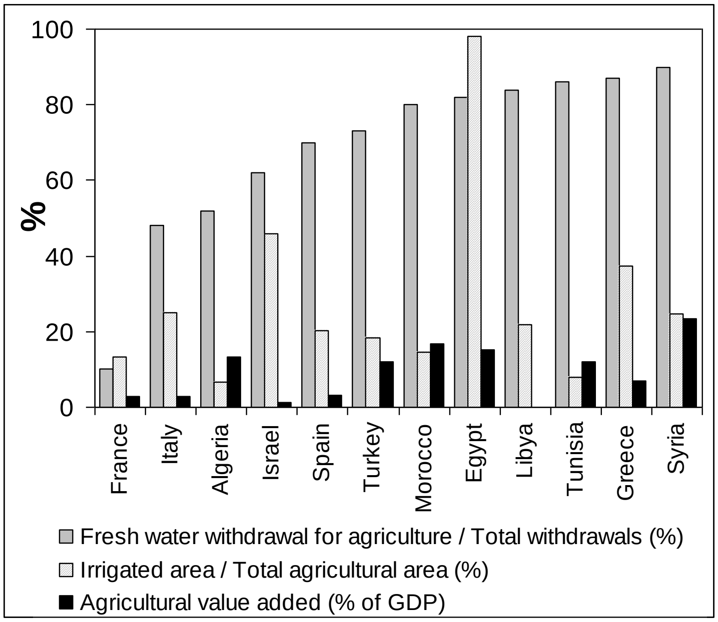


Figure 5 Water use for irrigation and irrigated agricultural areas in selected Mediterranean countries. Source of data: FAO, 2005

(c) Water quality

Water management problems are not an exclusive matter of water quantity but also of water quality. The environmental impacts human activities cause on water resources, have gained increased interest in recent years and water pollution has become a high priority issue for the protection of the quantity and the quality of the surface water and groundwater resources.

Degradation of the groundwater quality is a common problem in the Mediterranean region due to multiple pressures on the aquifers: excessive pumping in relation to average natural recharge, return flow from irrigation water with intense use of agrochemicals, leakage from urban areas, land fills, septic tanks, sewers, mine tailings, among others (Barraque, 1998; Fornes et al., 2005). Also irrigated agriculture in semiarid regions, although increases crop productivity and economic stability, however, it is one of the major diffuse source contributors to the contamination of surface and groundwater bodies, mainly from pesticides and fertilisers. Control of pesticides and optimization of fertilisation with crop uptake are essential management strategies for better control of irrigated agriculture. Drought episodes also contribute to the degradation of groundwater quality (Iglesias and Moneo, 2005) as a result of the overuse of aquifers. An important number of Mediterranean wetlands are affected by irrigation activities since their ecosystems depend to a significant degree on the sustainability of agro-ecosystems.

Habitats' conservation and agriculture have in many cases irreconcilable interests (Hellegers and van Ierland, 2003).

Many aquifer systems that naturally contain vast quantities of brackish water, have limited possibilities for exploitation for human or agricultural uses, imposing so, additional demand stress to neighbouring aquifers with higher water quality. Also saline intrusion is an important concern in aquifers, especially in the Mediterranean region, where as a result of the high seasonal water demand, mainly for tourism, they have been over pumped.

(d) Shared water

Almost one half of the Earth's land surface is covered by trans-boundary river basins and freshwater scarcity problems are becoming more frequent. Water can lead to political hostilities and many regions with political conflicts are sharing water resources. International Organizations need to address cooperation among nations in order to solve conflicts. Most Mediterranean freshwater and groundwater resources are shared among countries (Wolfe, 1999), the Nile River being a key global example. Within the Mediterranean countries, water shared between administrative regions is also common. Disputes exist, especially during drought conditions, which will probably increase as a result of imbalance distribution of water resources among the regions. Policies of central government or single basin management cannot resolve issues over shared water bodies, and local interests are likely to diverge. International Institutions can play a key role as official and independent mechanisms to deal with water related conflicts between the regions.

(e) Climate change

Climate change projections for the region derived from global climate model driven by socio-economic scenarios (IPCC, 2014) result in an increase of temperature (1.5C to 3.6C in the 2050s) and precipitation decreases in most of the territory (about 10 to 20% decreases, depending on the season in the 2050s). Climate change projections also indicate an increased likelihood of droughts (Kerr, 2005) and variability of precipitation – in time, space, and intensity – that would directly influence water resources availability. The combination of long-term change (e.g., warmer average temperatures) and greater extremes (e.g., droughts) can have decisive impacts on water demand, with further impact on the ecosystems. Under all climate change scenarios in the Mediterranean region, available water resources decrease while irrigation demand increases (Iglesias et al., 2006; Iglesias et al., 2011).

Under current conditions all Mediterranean countries also face significant problems due to the unbalanced distribution of water resources, conflicts among users, and between countries and it seems most likely that climate change will lead to an intensification of these problems. If climate change results in intensification of drought, available water resources in the Mediterranean region may become increasingly unstable and vulnerable. Drought management in both regulated and unregulated systems will have to adapt to the slow evolution of climate. The human dimension of climate change in the Mediterranean may not stop at the country' boundaries, since there is the potential for more

pronounced water conflicts with neighbouring regions (i.e. transboundary issues in the Nile and in many shared aquifers).

The management of the decreasing water resources, as a result of the climatic changes within the Mediterranean region, is challenged in particular, as climate change coincides with high development pressures, increasing populations, and high agricultural demands. Evidence for limited capacity to cope with socio-economic and agricultural demands in the Mediterranean region can be documented in recent history. For example, water reserves were not able to cope with extensive droughts in the late 1990's in Spain, Morocco and Tunisia, causing many irrigation dependent agricultural systems to cease production. Effective measures to cope with long-term drought and water scarcity are limited and difficult to implement due to the variety of stakeholders involved and the lack of adequate means to negotiate new policies.

E. Existing Information on Case Study's adaptation history

(Máx 2000 words)Please insert a short resume of the Case study existing information related to Climate Change Adaptation (major goals, plans, measures and timelines already defined or implemented), important Milestones in its "Adaptation Journey" as well as relevant state-of the art regarding the implementation of Adaptation Strategies and Specific Measure

(a) The context of drought and water scarcity management

Water scarcity and drought have multidimensional implications for society and therefore no single management action, legislation or policy can respond to all aspects and demand objectives. Mediterranean countries have developed legislation with different perspectives and levels of integration into the overall water management policy. When water is managed at the river basin level and the institutional responsibilities are clearly defined, drought legislation is more effectively applied. Nevertheless, a characteristic of all countries in the region is the weak cooperation among different institutions, and the fragmented roles of the State, the administrative regions and the river basin authorities, that often results in conflicts and impediments for implementation of existing legislation.

The European Water Framework Directive (2000/60/EC) is an example of recent efforts to develop coherent water management legislation, promote creation of institutions responsible for planning, management and control of water resources at the basin level. A main advantage of the explicit linkage of legislation and management to the basin level is the opportunity to address directly the needs and problems of the natural hydrological system and integrate the stakeholders in the decision process. However, the implementation of the Directive leads to difficulties, especially in transboundry basins – between countries or administrative regions of a country – where institutional coordination is required. Neither the current legislation nor the aforeseen implementation of the Directive, provide explicit regulations for the ecological quality of water bodies or the quality of the discharges in drought

situations. This important issue is being left to the discretion and responsibility of the various River Authorities.

Drought management needs to be integrated into the long-term strategies for water management incorporating improved early warning and monitoring systems (Iglesias et al., 2011). The development of specific drought contingency plans is at early stage in most countries. Example of detailed and operational plan is provided by the urban water supplier CYII that manages water for the metropolitan area of Madrid (Cubillo and Ibanez, 2003). The plan is based on the comprehensive understanding of the demands of the system, the strategic reserves of the stored volume and the level of guarantee for the water supply. It is surprising that international initiatives such as The United Nations Convention to Combat Desertification (UNCCD, 2002) that provides the global framework for implementing drought mitigation strategies, and the United Nations International Strategy for Disaster Reduction (UNISDR, 2002) that establishes a protocol for drought risk analysis, have not been taken into account for the preparation of the local drought management plans.

Water saving is a key strategy for overall reduction of societal vulnerability to drought. Water reuse and desalinization technologies at market rates and wide scale are recent but are developing fast, with significant efficiency gains, placing the cost at about 0.22 €/m3 and 0.48 €/m3 for brackish and sea waters respectively (Garrido and Iglesias, 2006). Irrigation technology is increasing water and land productivity with outstanding savings and benefits to ecosystems (Garrido and Iglesias, 2006). The adoption of water saving measures requires education and participation of the users.

Real public participation in water management is difficult to quantify, since participation in all countries is mainly theoretical. The data presented in the table is based in a comparative evaluation of the institutional analysis performed with a common methodology. It is difficult to compare results with other individual studies. For example Barreira (2003) carefully analysed the implications of the EU WFD for the Iberian peninsula, concluding low public participation, but does not provide a scale to compare with other Mediterranean countries. The level of participation evaluated in Table 2 reflects the proportion of stakeholders legally represented in water management bodies in each country. The ownership of surface and groundwater results to complications for the application of legislation and other aspects of water management. Common aspects of the region are the public ownership of surface water and the partially private ownership of groundwater, as well as the intensive groundwater use without restrictions or legal rights. Groundwater reserves have been and continue to be the largest buffer in water scarcity situations, but a large range of negative effects has been documented for its overuse (Llamas and Martinez-Santos, 2005).

Finally, economic instruments contribute to the design of effective management but alone are ineffective (Garrido and Calatrava, 2005). Water markets, tariffication, and reallocation of rights with financial compensation, may be adequate in some cases (Garrido et al., 2005). For example, data show that water markets or water transfer exchanging mechanisms are effective instruments during water shortages in Spain (Garrido et al., 2005).

(b) EU adaptation strategy

The European Union published in 2009 the White Paper on Adaptation to Climate Change: Towards a European framework for action (EU, 2009), which provides a framework to reduce the EU's vulnerability to climate change impacts. The White Paper, which was developed taking into account the replies to the 2007Green Paper on Adaptation to Climate Change in Europe: Policy Options for the EU.

The White Paper aims to support and strengthen, through an integrated and coordinated at EU level the measures to be taken at national or local level, which are the most appropriate for adaptation, due to the regional variability of the severity of climate impacts. The White Paper set out a two-stage strategy for adaptation to climate change impacts in the EU, supplementing the measures taken by Member States through an integrated and coordinated approach. The first phase run until the year 2012 and provided the basis for preparing a comprehensive EU adaptation from 2013.

In April 2013 the European Commission adopted an EU strategy on adaptation to climate change that aims to make Europe more climate-resilient. This strategy is focused on three key objectives: (1) promoting action by Member States, (2) “climate-proofing” action at EU level by promoting adaptation in key vulnerable sectors such as agriculture, fisheries and cohesion policy, and (3) better informed decision-making by addressing gaps in knowledge.

(c) Spanish Adaptation Plan (PNACC)

The National Adaptation Plan to Climate Change (MMA, 2006), designed as a framework for coordination among public authorities in the activities of assessing impacts, vulnerability and adaptation to climate change was presented in Spain in February 2006. The plan includes a variety of sectors, such as biodiversity, water resources, forests, agriculture, coastal areas, hunting and inland fishing, mountain areas, soils, fisheries and marine ecosystems, transportation, human health, industry and energy, tourism, finance, and planning and building insurance.

Four action lines have been established under the National Adaptation Plan (PNACC) second work program, which coordinate adaptation strategies for each sector nationwide. The first seeks to conduct sectoral assessment of impacts, vulnerability and adaptation to climate change. The second gives priority to the integration of climate change adaptation in the sectoral legislation. The third emphasizes mobilizing key actors in the sectors included in the Plan. Finally the fourth line promotes the establishment of a system of indicators of impacts and adaptation to climate change (MMA, 2006).

The Plan has as its ultimate objective "the integration of climate change adaptation planning across sectors and/or systems." It has several specific goals for various stages of implementation that, at the moment, include the development of scenarios and tools for assessing climate impacts, vulnerability and adaptation to climate change as well as promoting public participation.

The importance of water resources is recognized in the PNACC and it has a specific section that mentions a likely reduction in water yields as a result of climate change. The measures, activities and areas of work for assessment of impacts, vulnerability and adaptation relating to water resources identified in the PNACC include:

- Development of coupled regional models climate-hydrology that allow obtaining reliable scenarios of all the terms and processes of the hydrological cycle, including extreme events
- Development of water bodies ecological quality models, compatible with the application of the “Directiva Marco de Aguas” (Water Framework Directive DMA)
- Application of hydrological scenarios generated for the XXI century to other sectors highly dependent on water resources (energy, agriculture, forestry, tourism, etc...)
- Identification of the most sensitive indicators of climate change within the framework of implementation of the DMA
- Evaluation of possible water management system under hydrological scenarios generated for the XXI century
- Development of guidelines for incorporating in the process of Environmental Impact Assessment and Strategic Environmental Assessment considerations of climate change impacts and plans for water sector projects.

Many initiatives have been launched within the framework of the PNACC. For example, the Climate Change Health Observatory is created within this framework as an instrument to analyse, evaluate and track the effects of Climate Change on public health and on the National Health System, allowing the execution of adaptation policies to reduce the Spanish population’s vulnerability to climate change (Spanish Government, 2013). In 2011, in the context of the PNACC, it was also approved a ‘Plan of preventive actions of the temperature excess effects on health 2011’. This Plan establishes measures to be implemented by national authorities, autonomous communities and local authorities. It also establishes criteria to monitor mortality and other kind of information to preventively act against these health impacts. The strategy is based on the following activities:

- Temperature forecast from the data supplied by the Spanish National Institute of Meteorology (AEMET)
- Information to citizens about the effects of excessive temperature.
- Implementation of an information system for mortality and morbidity, for social and health services.
- Coordination of the social services in order to identify the vulnerable population, like children, elderly people.
- Emergency planning system, for first aid or hospital assistance.
- Coordination of the administrative and public authorities and the private sectors.

(d) Adaptation in the Madrid Region

Strategy on Air Quality and Climate Change (2006-2012) in The Autonomous Community of Madrid approved its 2007(Comunidad de Madrid, 2007). Although this Plan recognised the effects that air quality can have on health, and diagnosed air pollutants emissions over human health effect thresholds, the objectives and measures designed and implemented do not cover the health sector. It only defines measures related to air pollutants monitoring systems and its effects on health and related to enhancing the information to citizens when daily air pollutants thresholds are exceeded.

The city of Madrid joined the ***Climate Change Network of Spanish Municipalities***(*Red Española de municipios contra el CambioClimatico,* RECC)) in 2005 and the CoM (Covenant of Mayors) in 2008. The Plan of Sustainable Energy Use and Climate Change Prevention (*Plan de UsoSostenible de la Energía y Prevención del CambioClimático*) 2008-2012, was approved in 2008 as a requirement to join the CoM (Madrid City Council, 2008). The plan specially focuses on health issues within the measures regarding adaptation. It recognises the adverse effects of climate change on health of extreme temperatures, extreme events, air pollution, food and water diseases transmission. Within the adaptation measures, the plan established a monitoring system and a protocol of measures to face the pollen concentration, particulate matters and other air pollutants.

Plan of Alert and Prevention of heat waves. The consequences of the European heat waves of 2003 raised the awareness of the necessity to implement prevention plans to face heat wave risks. Before 2003, Rome and Lisbon were the unique cities to have such a plan. Therefore, in 2004 the Community of Madrid initiated a **Plan of Alert and Prevention of heat waves.** The main objective of the plan is to reduce the mortality and morbidity impacts of unusual increase in temperature. The plan consists in improving the information given to citizens about prevention measures and to professional health services and social authorities. This plan is activated annually from the 1st of June to the 15th of September. The warning system of this plan has defined the threshold of alert, based on the scientific literature described previously. In Madrid, the threshold has been estimated at 36.5°C, threshold above which mortality increases significantly. A second threshold is estimated at 38.5°C, where mortality increases deeply (Communidad de Madrid, 2013).

F. Connection with other research projects:

(Please list and shortly describe previous or ongoing research projects directly related with the Case Study) Please write the name and summary of the project, relevant partner institutions, year of beginning and end of project)

REFRESH

Adaptive Strategies To Mitigate The Impacts Of Climate Change On European Freshwater Ecosystems (REFRESH)

Summary. The future status of freshwater ecosystems is dependent on changes in land-use, pollution loading and water demand. In addition the measures that need to be taken to restore freshwater

ecosystems to good ecological status or to sustain priority species need to be designed either to adapt to future climate change or to mitigate the effects of climate change. Building on a previous EU FP6 Project, Euro-limpacs, REFRESH is concerned with generating the scientific understanding that enables such measures to be implemented successfully.

Institutions involved

University College London (Co-ordinator)/UCL.UK
Aarhus Universitet- National Environmental Research Institute/AU. Denmark
The University of Reading/UREAD. UK
Finnish Environment Institute/SYKE. Finland
Universitaet Duisburg-Essen/UDE. Germany
Alterra/ALTERRA. Netherlands
Natural Environment Research Council/NERC. UK
Swedish University of Agricultural Sciences/SLU. Sweden
The James Hutton Institute
Utrecht University/UU-BIO. Netherlands
Consejo Superior de Investigaciones Cient¡ficas/CSIC. Spain
Middle East Technical University/METU. Turkey
Forschungsverbund Berlin e. V/FVB. Germany
Commission of the European Communities - Directorate General Joint Research Centre EC-JRC EU
StichtingDeltares/DELTARES. Netherlands
UniversitaetfuerBodenkultur Wien/BOKU. Austria
Biology Centre AS CR Institute of Hydrobiology/BCAS. Czech Rep
EestiMaaülikool (Estonian University of Life Sciences)/EMU. Estonia
Universitat de Barcelona/UB. Spain
University of Patras/UPAT. Greece
Centre National de la Recherche Scientifique - Universite Paul Sabatier/CNRS-EDB. France
Norwegian Institute for Agricultural and Environmental Research/BIOFORSK. Norway
Norwegian Institute for Water Research/NIVA. Norway
Trent University/TRENT. Canada
Griffith University/GU. Australia

Date of the end of the project. 31.01.2014

RAMSES

EU FP7 RAMSES (Reconciling Adaptation, Mitigation and Sustainable Development for cities): The main aim of this research project is to deliver much needed quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities. RAMSES will engage with stakeholders to ensure this information is policy relevant and ultimately enables the design and implementation of adaptation strategies in the EU and beyond.The project will focus on climate impacts and adaptation strategies pertinent to urban areas due to their high social and economic importance.

Partner institutions: Potsdam Institute for Climate Impact Research, London School of Economics and Political Science, Newcastle University & Tyndall Centre for Climate Change Research, Flemish Institute

for Technological Research, IDDR - Institute for Sustainable Development and International Relations, TECNALIA Research & Innovation - Energy and Environment, NTNU Norwegian University of Science and Technology, World Health Organization Regional Office for Europe, T6 Ecosystem s.r.l., ICLEI - Local Governments for Sustainability, European Secretariat, Seneca Consultants sprl, Climate Media Factory UG, Institut Veolia Environnement.

RAMSES is a European Integrated Project, co-financed by the European Commission in the 7th Framework Programme in the call „ENV.2012.6.1-3 Strategies, costs and impacts of adaptation to climate change“. It has started on 1 October 2012 and will run until 30 September 2017.

VURCA

VURCA PROJECT: the Vulnérabilité URbaine aux épisodes Caniculaires et stratégies d'Adaptation (VURCA) project proposes an interdisciplinary approach where both environmental, technical and socio-economic aspects are considered, in order to provide first insights on the complex interaction between city economies and climate change and on the viability and effectiveness of identified adaptation options. From a methodological perspective, this is expected to be achieved by integrating in a unique investigation framework the outcomes from three different analytical methods:a climate model,a urban-weather modeland a coupled housing-transportation model.

EuroHEAT

EuroHEAT – Improving public health responses to extremeweather/heat waves. It was coordinated by the WHO Regional Office forEuropeand co-funded by the European Commission (EC) Directorate-General for Health and Consumers (DG SANCO), has quantified thehealth effects of heat in cities in the WHO European Region and hasidentified options for improving the preparedness of health systemsand their responses to protect health.

Peseta I and PESETA II

Peseta I and PESETA II - Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis proposes a multi-sectoral assessment of the impacts of climate change in Europe for the 2071-2100 time horizon. PESETA considered the impacts in five areas: agriculture, coastal systems, river floods, tourism and human health. PESETA II extends the coverage to nine areas, adding energy, transport infrastructure, forest fires, and habitat suitability. Furthermore, while PESETA looks at four climate runs, in PESETA II up to 15 climate runs have been modelled by some of the sectoral teams.

G. Case ID, Typologies and Dimensions

Having in mind the following BASE Objectives; Categories of Case Studies, please fill in the following table.

BASE OBJECTIVES
1.Compile and analyse data and information on adaptation measures, their effectiveness. (…)
2.Improve current, develop new and integrate methods and tools to assess climate impacts, vulnerability, risks and adaptation policies (…).
3.Identify conflicts and synergies of adaptation policies at different levels of policy making with other policies (including climate mitigation) within and between sectors. (…)
4.Assess the effectiveness and the costs and benefits of adaptation strategies to be undertaken at local, regional, and national scales using innovative approaches (mainly by integrating bottom-up knowledge/assessment and top-down dynamics/processes) with particular attention on sectors of high social and economic importance.
5.Bridge the gap between specific assessments of adaptation measures and top-down implementation of comprehensive and integrated strategies.
6.Use and develop novel participatory and deliberative tools to enhance the effective use of local contextualized knowledge in adaptation strategies to assess perceptions of adaptation pathways and their co-design by citizens and stakeholders.
7. Disseminate findings by sharing the results of the project with policy-makers, practitioners and other stakeholders. (…)

CASE STUDIES CATEGORIES
A. Public administration (municipality, regional, national, European)
B. Research and education Centres (universities, research centres, projects and groups, schools)
C. Public companies
D. Companies (farms, SMEs, big businesses)
E. Social enterprises (cooperatives, non profit companies, woofing farms, etc)
F. Consortiums (partnerships, campaigns),
G. NGOs (environmental NGO, local development NGO, charities, etc)

H. Transition Initiative

I. Ecovillage

J. Informal groups, Movements

Case ID			Typologies and characterization				
Country & Name of CS	BASE Objectives to be answered by the CS	Category of case study	Territorial zones	Scale	Process Direction	Temporal Definition	Timescale[1]
Spain, Tagus Water District	☐ Objective 1 ☑ Objective 2 ☐ Objective 3 ☑ Objective 4 ☐ Objective 5 ☑ Objective 6 ☐ Objective 7	A, B, C, D	☑ Rural ☑ Urban ☐ Coastal ☑ River Basin	☑ Local ☑ Regional ☐ National ☐ Transnational ☐ European /Global	☑ Bottom-Up ☐ Top-Down	☐ Retrospective ☑ Prospective	2013–2015

H. Impacts, Sectors and Implementation

Please tick the relevant boxes for impacts and implementation and insert the number 1 for primary sector and the number 2 for secondary sector.

Impacts	Sectors	Implementation

[1]Please insert year of start and year of end of case study.

Primary CC Impacts (Climate-Adapt)	Primary CC Impacts (BASE)	Primary and Secondary Sector (Climate Adapt)	Primary and secondary Sector (BASE)	Implemented[2]	Phase of Implementation[2]
☑ Extreme Temperatures ☑ Water Scarcity ☐ Flooding ☐ Sea level Rise ☑ Droughts ☑ Storms ☐ Ice and Snow	☑ Extreme temperatures ☑ Water scarcity ☐ Flooding ☐ Coastal Erosion ☑ Droughts ☐ Soil Erosion ☑ Vector Borne Diseases ☑ Damages from extreme weather related events (storms, ice and snow)	☑ Agriculture and forest ☑ Biodiversity ☐ Coastal Areas ☑ Disaster risk reduction ☐ Financial ☑ Health ☐ Infrastructure ☐ Marine and Fisheries ☑ Water Management ☑ Urban	☑ Agriculture ☑ Biodiversity & Ecosystems ☐ Coastal and Marine systems ☐ Energy ☑ Health and Social Policies ☐ Transport ☐ Production Systems and Physical Infrastructures ☑ Water resources ☐ Tourism	☐ Yes ☑ Ongoing ☐ No	☑ Assessment ☑ Planning ☐ Implementation ☐ Monitoring ☐ Evaluation

I. Importance and Relevance of Adaptation

Please tick the relevant box for the case study.

☑ Case developed and implemented as a climate change adaptation measure

☐ Case developed and implemented and partially funded as a climate change adaptation measure

[2] When the case study consists of a public administration with a top down approach, implementation can be an approved legislation or regulation. When the case study is about practical adaptation measures like a sand dune, for example, implementation should be considered finished when the dune is built in situ.

☐ Case mainly developed and implemented because of other policy objectives, but with significant consideration on climate change adaptation aspects

Case study research Methodology

A. Research Goals

(Máx 500 words) Please insert which are the General Goals for the case study as well as how will the case study contribute for BASE projects and BASE key research questions.

(a) Overall approach

The case study is focused on climate adaptation to water shortages and health effects in the Tagus Water District of Spain, predominantly in urban municipalities: Madrid metropolitan area that comprises 22 municipalities.

Here we provide a framework to define alternative policy choices for adapting water and health in the Tagus Water District, considering climate change projections. The case study of focuses on climate adaptation to water shortages and health effects in the Tagus Water District of Spain, predominantly in urban municipalities: Madrid metropolitan area that comprises 22 municipalities. The aim is to identify the co-benefits of the adaptation strategies in different sectors. The scales of analysis are: local and regional. The local stakeholders inform the regional assessment of water and health adaptation options.

The design the adaptation strategies organized around the idea that understanding resilience, policy trade-offs, and flexible mechanisms.

We analyse adaptation by a number of approaches: modelling, a range of participatory approaches and statistical methods.

The case study will develop a methodological framework to assess costs and benefits of cross-sectoral adaptation strategies to reduce the impacts of heat waves in the area of Madrid. The analysis will focus on the co-benefits of a set of adaptation measures in different sectors. The area of Madrid has been chosen as a case study due to its multiple vulnerabilities due to climate change, its large size and population, its drought-prone climate and its use of trans-boundary water. The study will identify measures with co-benefits specifically on water and health and assess their costs and benefits.

Identifying and calculating co-benefits is one of the most effective ways to prioritize adaptation measures, and this can only be done through participatory approaches. In this sense, the case study will use a participatory process to get information from the stakeholders about the complexity of the

system, about their feedbacks and main drivers, responding to the questions of: What are the impacts of heat waves in the city of Madrid? What are the potential adaptation measures? This will be done through the method Fuzzy Cognitive Mapping (FCM) which allows modelling the system in a semi-quantitative way and simulating policy options (running different policy scenarios). This information used to feed the cost-benefit analysis (CBA) of a selection of adaptation measures also obtained from the process of interviews to the stakeholders. Additionally and also with the intention to feed the CBA, a health impact assessment (HIA) based on different climate scenarios will be performed. This way the case study will fulfil 5 specific objectives: (1) study direct and indirect impacts of heat waves on health in the city of Madrid and outskirts; (2) establish synergies (co-benefits) and tradeoffs between sectors; (3) robust understanding of system complexity (using of causal networks informed public authorities and researchers), (4) economic valuation (benefits and costs) of selected measures; and (5) provide information to local policy makers.

(b) Water resources

The case study will analyse the effect of water shortage in different sectors in the Tagus Water District understanding that the use of water on the city of Madrid has trade-offs with other users and the environment. It will focus on understanding barriers and motivations that may hinder or help the implementation of adaptation policies.

(c) Health

The Heath case study will fulfil 5 specific objectives: (1) study direct and indirect impacts of heat waves on health in the city of Madrid and outskirts; (2) establish synergies (co-benefits) and trade-offs between sectors; (3) robust understanding of system complexity (using of causal networks informed public authorities and researchers), (4) economic valuation (benefits and costs) of selected measures.

This will be done by using a participatory approach and combining different methods (see methodology section) that will allow the research team to assess the costs and benefits of different adaptation measures taking into account the system's complexity and the health impacts foreseen according to the climate scenarios for the following years.

B. Stakeholders involved

(Máx 2000 words) Please insert any information about the stakeholders involved in the adaptation process with which you will relate to, namely their nature, involvement in the process, etc. If possible highlight the decision-making process as well as the leadership process for Climate Adaptation Strategies. Do mention if there is any kind of public engagement and participation within the Adaptation process.)

The objectives of the case study that wants to look for co-benefits in the water and health sectors led us to ensure the involvement of the Observatory of Health and Climate Change —an organism depending

on the Health Ministry— as the main stakeholder. This implied to establish a framework in which both the research project and the Observatory would benefit, and also to involve them in the stakeholder selection process, which was carried out through a series of meetings at the Ministry.

The stakeholder selection criteria prioritized the participation of those positions that they may hold decision-makers or the ability to influence the decision making process. Citizen's participation was limited to NGOs and Farmer's Unions.

Thirty stakeholders were identified and invited to a Focus Group held at the Technical University of Madrid (UPM) on 19 November 2013 (Table x).

Table 2 Stakeholders included in the Focus Group exploring adaptation measure in water resources in the Tagus Water District

Stakeholder group	**Participants in the Focus Group**
National Administration	Water Quality Department, Ministry of Health, Observatory of Health and Climate Change. Spanish Office for Climate Change (OECC)
Regional Administration	Health Department of the Navarra Regional Government Water Management Department of the Madrid Government
Madrid Municipality	Water Management of the Municipality of Madrid
Water supply company	Scientific Area of Fundación Canal de Isabel II
Industry	Hydropower (Iberdrola)
Agriculture	Farmer's Unions (COAG)
Scientific community	Transyt (Transport research centre) Centre for Hydrological Studies (CEDEX) University of Barcelona, Department of Meteorology

In a first step, a stakeholder meeting was organized in November 2013 to understand the socio-economic and political context of impacts and adaptation in the region of Madrid. This first meeting involved 11 stakeholders including representatives of the Spanish Ministry of Health, Social Services and Equity, Madrid municipality, Madrid community (regional level), the Spanish Climate Change Office, the Health department of the government of Navarra, the water utility foundation Canal Isabel II, a union of farmers, the electricity company Iberdrola, experts from the Autonomous University of Barcelona and Polytechnic University of Madrid.

In a second round, personal interviews with stakeholders were performed during May 2014. This participatory process was realised to get information to be used in the FCM to elicit information about the perceived impacts and adaptation options from different expertise angles in the city of Madrid. This involved the participation of 24 stakeholders including researchers and public authorities (only a few of them participated in the first round) and different areas of expertise as the figures below show:

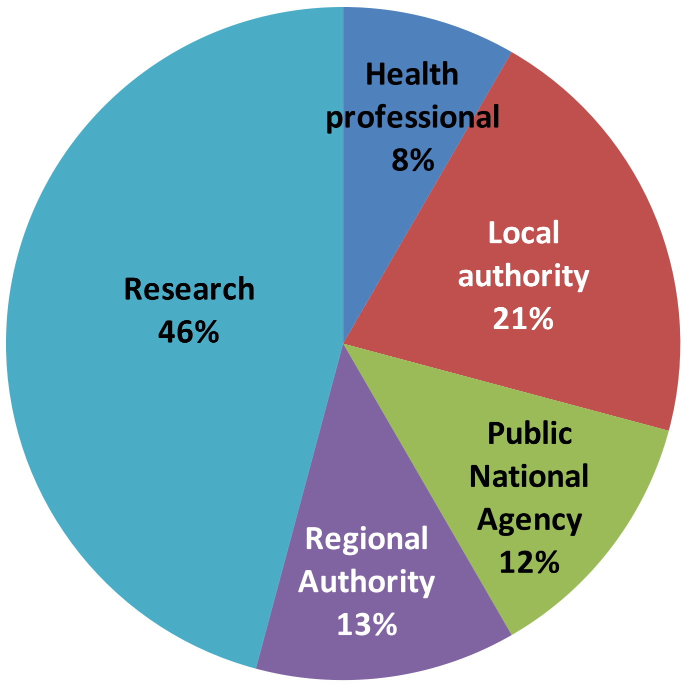


Figure 6 Composition of the Stakeholders included in the round of personal interviews

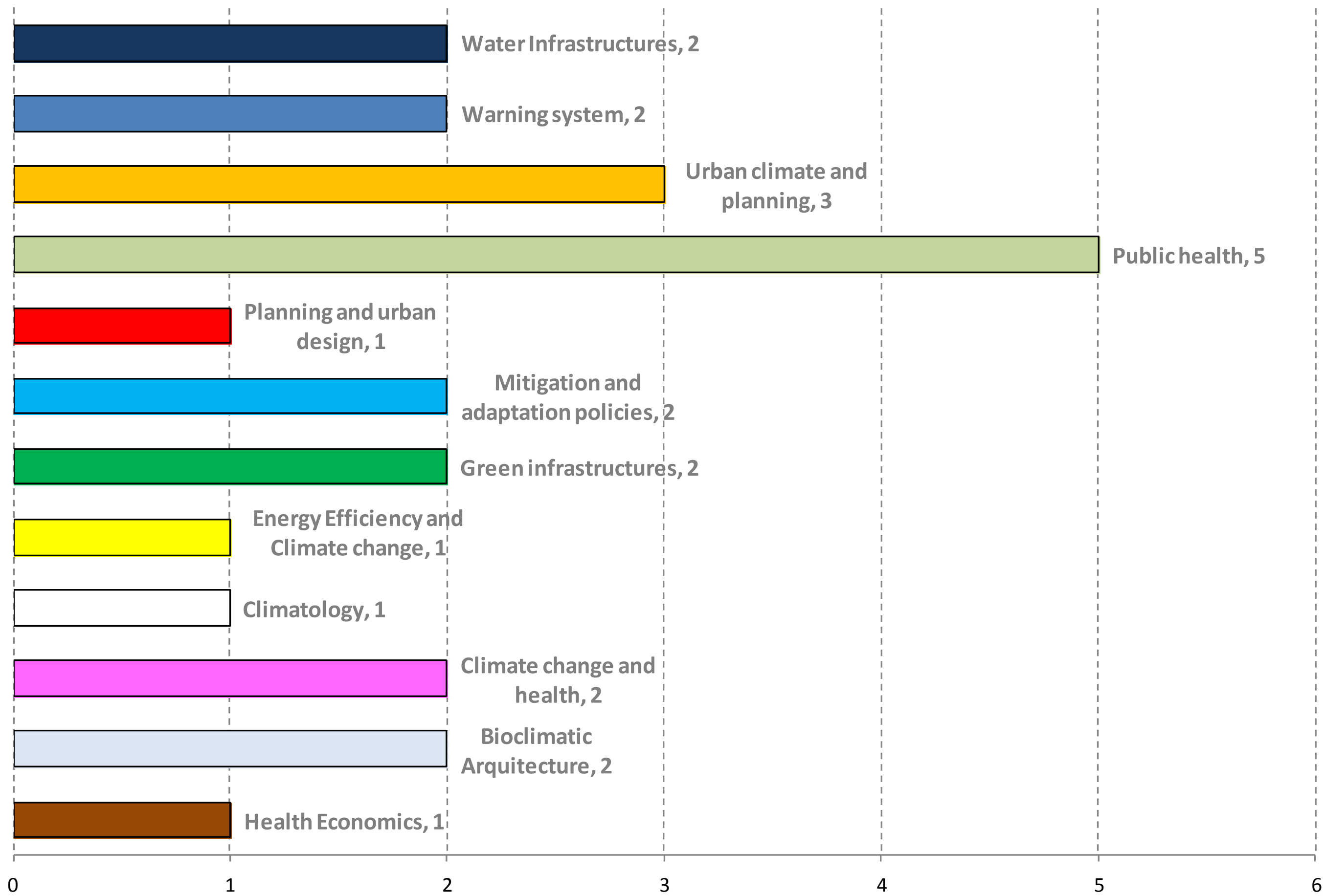


Figure 7 Areas of expertise of the stakeholders involved in the Fuzzy Cognitive Mapping process

C. Methodology

(Máx 2000 words) Please insert what will be your research approach regarding this case study, how did you define it (did it include participatory sessions or not) and how you will implement it during the BASE Project period.

(a) Water management and public barriers and opportunities

The water resources study includes three components (Figure x).

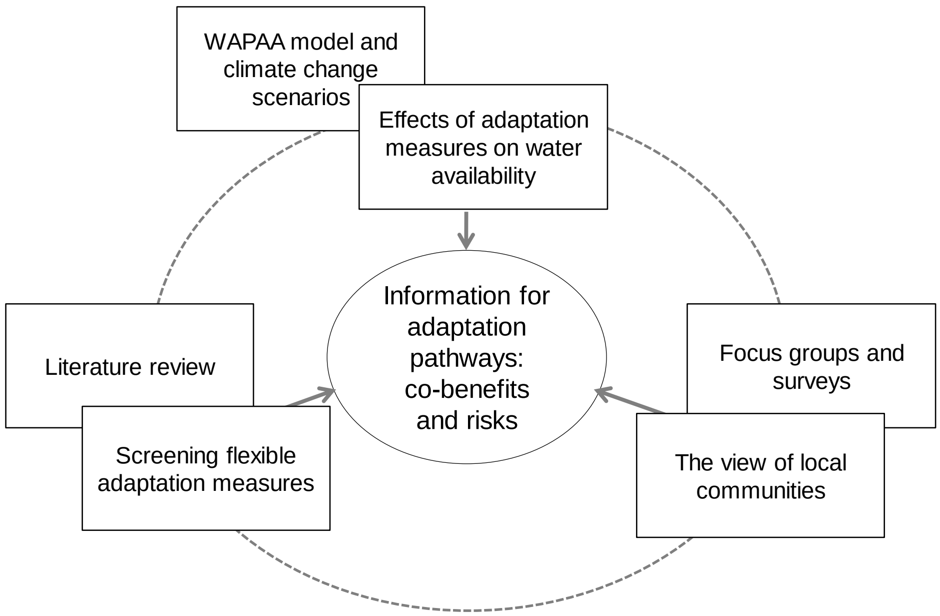


Figure 8 Methodological framework for the evaluation of adaptation strategies of water management in urban areas

First a diagnostic of the water available to urban areas, agriculture and ecosystems is evaluated by using the WAAPA model. This links the case study with the continental study in BASE. Second, a literature review provides a screening of the flexible adaptation measures that may be implemented in response to the climate risks. In the third step, the strategies are tested by participatory approaches. This includes a panel of experts to discuss the adaptation options in view of projected impacts. This is carried out by means of a focus group. Finally, the adaption options are evaluated by the citizens of the Madrid metropolitan area, by means of surveys.

An important component is the analysis of the citizens' response. The case study will explore the incentives and barriers of the civil population to implement the adaptation strategies. This is based on a panel survey in the 22 municipalities, with the aim of defining:

- How do citizens perceive climate adaptation and the need for climate adaptation actions? What is their risk perception?
- What climate adaptation actions they know (if any)? And what are the costs? Are there any experienced benefits?
- Do citizens experience any conflict between climate adaptation policies and other policies (e.g. urban planning)?

The case study builds on previous knowledge and proposes a four steps method involving the main stakeholders at different scales. The first step involves National Regional and Local Administration decision makers with key actors of Water, Energy and Agriculture sectors in a workshop to exchange information on vulnerabilities and identify adaptation pathways. The second step —carried out through

a Fuzzy Cognitive Mapping method, with twenty five experts— looks for a semi quantitative weighting of measures.

(b) Analysis of public choices

We have designed a specific methodology as follows:

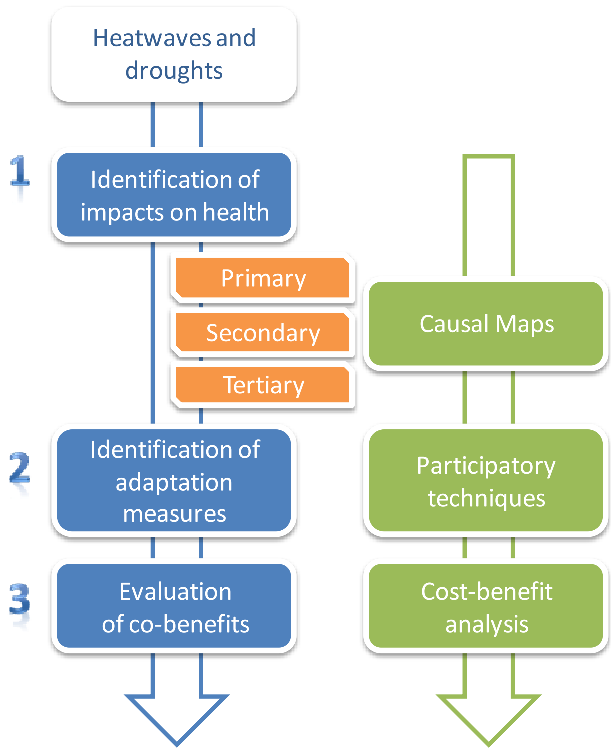


Figure 9 Methodological approach

In Step 1, we improve the understanding of the linear and non-linear cascading effects that can be caused by climatic impacts, i.e. the primary, secondary and tertiary effects related to heat waves and droughts on health. This information is used in Step 3 to maximize co-benefits of planned adaptation measures, which will be identified with the stakeholders beforehand in Step 2.

Conceptual Mapping (Fuzzy Cognitive Mapping FCM) to obtain semi-quantitative causal networks on impacts and adaptation measures informed by stakeholders and researchers

Causal reasoning can be used to aid in this process of identifying cause-effect relations. In this case study we will use casual diagrams as a tool to identify potential co benefits among adaptation measures which will be later assessed using traditional cost-benefit analysis tools (see Step 2).

Causal reasoning is used as a base in many methods such as bayesian networks or systems dynamics modelling. In this case study we will use Fuzzy Cognitive Mapping through a participatory process where stakeholders related to city services management will be involved. Fuzzy Cognitive Mapping (FCM)—a participatory semi-quantitative interview and analysis method (see Glykas, 2010; Özesmi and Özesmi, 2004; Stylios et al., 1997)—emerges as an extremely useful tool for complex decision environments as it is able to aggregate the accumulated experience, knowledge or perception of experts or actors. Participants are required to translate their knowledge or experience into a map (or network) consisting of nodes and weighted interconnections, which represent states of the system and the weighted cause-effect relations between them. FCM provides information on the main features of the network and allows evaluating scenarios of policy options or decision alternatives. This application of FCM will be extremely useful for our case study objectives as it will allow assessing the changes in the system under different scenarios of adaptation pathways.

Cost benefit analysis on selected nodes

Different methods are used by economists to evaluate if the cost of a measure is justified in terms of the results obtained. Public health has usually used cost-effectiveness analysis (CEA), which estimates the cost of achieving a certain health impact, measured as number of deaths, cases or DALY avoided. The method is used to identify the measure with the highest cost-effectiveness. Cost-benefit analysis (CBA), on the other hand, estimates and compares costs and benefits in monetary terms, in order to identify the measure with the highest net benefit. Both methods focus on the social costs of implementation, defined as the aggregated opportunity costs incurred by the society if the measure is put in place. The costs of a measure are those associated to the direct implementation of the measure, to the effort needed to improve adaptive capacity (institutional costs such as those related to infrastructures, training, information) and to the resource reallocation, these latter being usually not included as difficult to estimate.

Estimation of a model to characterize how threshold temperature can change in time

Global sensitivity analysis for CBA and temperature-health assessment model.

(c) Summary table

METHODS to be used in Case Studies[3]	YES // NO
Methods for prioritizing adaptation options	
Cost-Benefit Analysis (CBA)	YES
Cost-Effectiveness Analysis (CEA)	NO
Multi-criteria Analysis (MCA)	YES
Analytic Hierarchy Process (AHP)	NO
Quantification of impacts and relationships between factors affecting adaptation	
Causal Diagrams	YES
Influence Diagrams	YES
Process-based Modelling	YES
Welfare variation analysis under restrictions	NO
Uncertainty and sensitivity analysis	
Probabilistic multi model Ensemble	NO
Monte Carlo simulations (PRIMATE uses this method)	NO
Real option analysis	NO
Climate risk management process	NO
Global sensitivity analysis	YES
Participatory Methods	
Scenario Workshop	NO
Participatory Cost Benefit Analysis (PCBA)	YES
Participatory add-ons to CBA	NO
Participatory add-ons to Multi Criteria Decision Analysis	YES

[3] For descriptions and references of the Methods please refer to Milestone 8. For data requests from specific Work Packages please refer to Deliverable 4.1

Participatory add-ons to Adaptation Pathways	NO
Fuzzy Cognitive Mapping	YES

(Máx 500 words)Please highlight if you have any special need or focus regarding any of these methods and their use on your case study.

D. Case study Timeline

(Please insert and image/graph of the Timeline of your Research Approach, highlighting important milestones and deliverables.)

The timeline is sunnarised in Table x.

year												2013												2014			2015
month			3			6			9			12			3			6			9			12			3
				5.1 Case Baselines																							
									5.2 Impacts, costs and benefits																		
							5.3 Adaptation Strat.																				
																5.4 Methodologies and tools											
																			5.5 Comparison of cases								
Tasks																											
Deliverables										5.1					5.2						5.3			5.4			5.5
Milestones			13																						14		
Case	Literature review																										
Actions																											
					Stakeholder consultation																						
													Development and coordination														
																		Scientific papers									
Meetings					1						2				3			4		5		6	7	8			

Table 3 Summary of the timeline

E. Collaboration with other Partners and Case studies

Collaboration with BASE case studies (see list in EMDESK):

Case: Kalajoki; Person: Anne-Mari Rytkönen

Case: Danish Agriculture; Person: Anders Branth Pedersen and HelleØrsted Nielsen

Case: Agriculture in Portugal; Person: Filipe Alves

Collaboration within BASE partners/researchers (EX: for a specific competence):

Name: Gil Penha-Lopes , Maria Coelho, Ines Campos, Filipe Alves , Andre Vizinho ; Partner: FFCUL

Name: Anders Branth Pedersen, Helle Ørsted; Partner: Aarhus

Name: Ad Jeuken, Marjolijn Haasnoot; Partner: Deltares

Name: Ibon Galarraga, Aline Chiabai, Anil Markandya, Sébastien Foudi, Marta Olazabal; Partner: BC3

Name: Andreas Hastrup Clemmensen; Partner: Danish Board of Technology

Name: Anne-Mari Rytkönen; Partner: SYKE

Name: Dabo Guan; Partner: University of Leeds

Name: Tim Taylor; Partner: The University of Exeter

Name: Margaretha Breil; Partner: CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI

Name: Volker Meyer,; Partner: HELMHOLTZ-ZENTRUM FUER UMWELTFORSCHUNG GMBH – UFZ

Name: Maria Hubtova; Partner: CENTRUM VYZKUMU GLOBALNI ZMENY

F. Research Outputs

(Ongoing work, will be filled in later in the case study development process)

List of papers and conferences

Scientific Publications

- Interim reports + final case study report for D5.5 (Month 30)

- Scientific papers: #

Ciscar JC, Perry M, Iglesias A, van Regemorter D (2014) Agriculture, Climate Change and the Global Economy. Environmental and Resource Economics (submitted)

García de Jalón S, Iglesias A, Cunningham R, Pérez Díaz JI (2014) Building resilience to water scarcity in Southern Spain: A case study of rice farming in Doñana protected wetlands. Regional Environmental Change, 14, 1229-1242

García de Jalón S, Iglesias A, Quiroga S, Bardají I (2013) Exploring public support for climate change adaptation policies in the Mediterranean region: A case study in Southern Spain. Environmental Science and Policy, 29, 1-11.

García de Jalón S, Silvestri S, Iglesias A (2014) Responding to climate change? Behavioural barriers to adopt changes in agricultural communities: an example from Kenya. Regional Environmental Change (accepted)

Garrote L, Iglesias A, Granados A, Mediero L, Martín-Carrasco F (2014) Quantitative assessment of climate change vulnerability of irrigation demands in Mediterranean Europe. Water Resources Management (in press) 10.1007/s11269-014-0736-6

González-Zeas D, Garrote L, Iglesias A, Granados A, Chávez-Jiménez A (2014) Hydrologic determinants of climate change impacts on regulated water resources systems. Water Resources Management (in press)

González-Zeas D, Quiroga S, Iglesias A, Garrote L (2013) Looking beyond the average agricultural impacts in defining adaptation needs in Europe. Regional Environmental Change, 13(1), 1-11

Iglesias A, Garrote L (2014) Adaptation strategies for agricultural water management under climate change in Europe. Agricultural Water Management (in second revision)

Martin-Carrasco F, Garrote L, Iglesias A, Mediero L (2013) Diagnosing Causes of Water Scarcity in Complex Water Resources Systems and Identifying Risk Management Actions Water Resources Management, 27(6) 1693-1705

Plaza-Bonilla D, Arrúe JL, Cantero-Martíne C, Fanlo R, Iglesias A, Álvaro-Fuentes J (2014) Carbon management perspectives in dryland agricultural systems. Carbon Management (in press)

Resco P, Iglesias A, Bardají I, Sotés V (2014) Climate change and wine regions in Spain: risks and opportunities. Submited to Climatic Change.

Other Publications

- Books/Books Chapters: # 1

Iglesias A, Water and people. (2013). In: Navarra A, Tubiana L (Eds) (2013) Regional Assessment of Climate Change in the Mediterranean: Volume 2: Agriculture, Forests and Ecosystems Services and People, Springer, The Netherlands (ISBN10: 9400757719 ISBN13: 9789400757714

Olazabal M., Neumann M.B., Chiabai A. and Foudi S. Navigating urban complexity through stakeholders' experiences and knowledge. UGEC Viewpoints. July 2015. Forthcoming

Other
Scientific conferences: # ___

Title: Co-benefits on cross-sectoral adaptation strategies to reduce climate change impacts in Mediterranean cities. Conference: The Mediterranean City: Adaptation Strategies to Global Environmental Change in the Mediterranean City and the role of Global Earth Observation. Athens. Month/Year: 06/2014

Title: Building robust strategies for climate proof fresh water supply: Tagus basin: Looking into solutions, dilemmas, responsibilities and cooperation. Conference: European Climate Change Adaptation Conference. Hamburg. Month/Year: 03/2013

Foudi S, Chiabai A., Neumann M. and Spadaro J. Urban ecosystem services from green roofs: costs, benefits and uncertainties at the city scale. ECCA European Climate Change Adaptation Conference. Copenhagen, Denmark.

Olazabal M., Chiabai A., Neumann M.B. and Foudi S. Fuzzy Cognitive Mapping to enhance climate change adaptation to heatwaves in the city of Madrid. ECCA European Climate Change Adaptation Conference 2015. Copenhagen, Denmark.

Invited seminars, presentations at local events, etc…

Participation in Climate Change Adaptation

A. Process overview

(Please describe the use of Participatory Methodologies within your case study, namely its integration in the overall Research Methodology explained earlier in the CSLD, the rationale behind it and key expected outcomes – Máx 1000 words)

The participatory methodology of the Tagus River Water District follows a process with three phases, involving stakeholders, experts and citizens in three different scales: National, Regional and Local

- Phase 1: interviews and Focus group

Being one of the objectives of the case study exploring co-benefits in the water and health sectors, we had to ensure the involvement of the Observatory of Health and Climate Change —an organism depending on the Health Ministry— as the main stakeholder.

We held a series of meetings at the Ministry in 2013 in which we discussed the main adaptation topics and identified the stakeholders. The stakeholder selection criteria prioritized the participation of those positions that they may hold decision-makers or the ability to influence the decision making process.

Citizen's participation was limited to NGOs and Farmer's Unions.

Thirty stakeholders were identified and invited to a Focus Group held at the Technical University of Madrid (UPM) on November 2013.

- Phase 2: Fuzzy cognitive Mapping

The second phase was the Fuzzy Cognitive Mapping, a participatory semi-quantitative interview and analysis method (see e.g. Glykas, 2010; Özesmi and Özesmi, 2004) in which personal interviews with experts were performed during May 2014. The objective of the method is to identify cause-effect relations through causal reasoning More specifically, we used casual diagrams to identify potential co-benefits among adaptation measures in a semi-quantitative way which can be later assessed using traditional cost-benefit analysis tools (see section D). We apply this method in the context of climate change and focus on health related outcomes.

FCM is a valuable tool for complex decision environments as it is able to aggregate the accumulated experience, knowledge or perception of experts or actors. Participants are required to translate their knowledge or experience into a map (or network). This maps consists of concept nodes and weighted cause-effect relations between concepts nodes (Figure 10). FCM provides information on the main features of the network and allows evaluating scenarios of policy options or decision alternatives.

- Phase 3: Survey

Finally a survey is going to be conducted in Madrid Region with the aim to study public support for adaptation policies. A Logit model will be utilized to analyse which predictors positively or negatively affect people's support for adaptation policies, in order to determine the main barriers and incentives for the implementation of these policies.

B. Participation in the Process Phases

(Please uncover the role of all participants in the process of implementing adaptation measures. The adaptation implementation has been divided into four phases for purposes of ease: 1) Initiative/decision to act, 2) Development of potential adaptation options, 3) Decision-making, and 4) Implementation. The process phases are to be filled out with information corresponding to each participant. I.e. if experts were not consulted in the 'decision-making' phase, then describe why they were not included. It is also important that a wide array of participants is described, including those that were excluded from parts of the process.)

Make a bullet point for each of the five participant categories below (and distinguish between for example different stakeholder or expert groups) and be as descriptive as possible how, why/why not were they involved.

Process phases:

1. Initiative/decision to act

The initiative came from the case study research team. Nevertheless the Case study is being integrated in the Spanish Office for Climate Change which means that the results will have an effect on legislation.

Stakeholders:

- None

Citizens:

- No

Experts:

- UPM team, including agriculture, hydrology and urban planning sectors.
- BC3 team, including economy, infrastructures, climate and health sectors

Politicians:

- No

Officials/legislators:

- The Spanish Office for Climate Change

2. Development of potential adaptation options

Stakeholders:

- National Administration (Water Quality Department, Ministry of Health, Observatory of Health and Climate Change, Spanish Office for Climate Change (OECC))
- Regional Administration (Health Department of the Navarra Regional Government, Water Management Department of the Madrid Government)
- Madrid Municipality (Water Management of the Municipality of Madrid)
- Water supply company (Scientific Area of Fundación Canal de Isabel II)
- Industry (Hydropower (Iberdrola))
- Agriculture (Farmer's Unions COAG)

Citizens:

- A survey is going to be performed on the Madrid Metropolitan Area

Experts:

- UPM team, including agriculture, hydrology and urban planning sectors
- BC3 team, including economy, infrastructures, climate and health sectors
- Transyt (Transport research centre)
- Centre for Hydrological Studies (CEDEX)
- University of Barcelona, Department of Meteorology

Politicians:

- No

Officials/legislators:

- The Spanish Office for Climate Change

3. Decision-making

The case study has a prospective character with the aim of identifying co-benefits on cross-sectoral adaptation strategies and will not go into the decision-making process, which will correspond to the Office of the Climate Change out of the time frame of the BASE project.

4. Implementation

The possible implementation process of the adaptation measures goes out of the time frame of the BASE project.

C. Participation Experience

(Please report with regards to your case study and the implementation of Participatory Methodologies using a traditional SWOT analysis – Strengths; Weaknesses; Opportunities and Threats)

Strenghts	Weaknesses
- Collect data from the main sectors affected: - participatory methods enable to collect data in a relative short time period (during interviews) - Identify synergies and trade-offs between sectors: the FCM (Figure 10) helps identify the most important concept nodes - Direct access to stakeholders' knowledge: participatory methods enable to collect data in a relative short time period (during interviews). Cost estimates of HHWS, potential for green future green infrastructure can be obtained during interviews for example. Adaptation options can be preliminary tested with stakeholders (results in Table 4) - - Learn from ongoing adaptation strategies already implemented or planned. In the case of Heat-Health warning system (HHWS) for example, scientific experts call our attention to the fact that temperature threshold defined by the current HHWS are inappropriate. Therefore a relevant adaptation measure would be a plan with a temperature alert that could significantly save more lives. - Identify unintended (negative or positive) impacts of adaptation policies. The FCM as described in next section enable to draw a picture of the causal relationship of complex concepts interconnections like the one of climate change, health outcomes and adaption measures. The method enables to draw a complete and detailed view the potential impacts.	- The results (the most beneficial adaptation options) are not going to be implemented on the short term - Access to data related to costs could be limited (review in a later stage) - Time constraint and limited capacity to obtain knowledge. Interviews of the FCM lasted 1hour and 30 minutes on average which is already quite large. Information required to obtain a model based CBA (ie non full participatory CBA) is large and stakeholders have time constraints. - FCM cannot estimate directly costs and benefits.

Opportunities	Threats
- Strengthen knowledge - Share knowledge between sectors - Raise stakeholders' interest towards climate change issue: enable to bring the issue directly at stakeholder level when most of the time climate change is not an immediate issue (day by day) dealt with by stakeholders. - Scientific: potential complementary of FCM with Cost-Benefit analysis. FCM could be used to test the robustness of a CBA, and the capacity to list all the potential benefits/costs. FCM enables to obtain the typology of costs and benefits from stakeholders and their weighted interrelations. The CBA estimates them. - Some information obtained in participatory process can served as a starting point for further scientific investigation on causal relationship. This gives more robustness to the results. This is the case with the epistemiologic relationship between temperature and mortality. - Opportunities to disseminate results of research back to stakeholders.	- Give excessive weight to experts and practitioners due to the design of the methodology which makes that most data are collected from them. - Potential bias in the causal relationship estimation (FCM) depends on representativeness and diversity of stakeholders. A biased analysis will threaten the relevancy of adaptation measures and their implementation.

D. Learning through Participation

In order to capture how participation could improve the climate change adaptation process, please report with regards to your case study:

- Your view whether and how participation influenced the strategies and measures decided in your case?

Heat and health case study

During each interview, the tasks of the 24 participants[4] of the FCM were:

[4] In some occasions, participants preferred to work in groups. This was the case of two couples and the reason why out of 24 participants, we got 22 maps

i. to develop their mental map responding to the question "what are the impacts of heat waves in the city of Madrid?" according to their perception, experience and knowledge. In this first stage they were asked to list the most important factors that have a role in this phenomenon and its impacts. Secondly, they were asked to connect them signing the relations in positive or negative. Lastly, they were asked to weight in a range from 0 to 1 (regardless of being negative or positive) with one or two decimals such connections depending on the certainty of their connection (which in most cases they understood this as, the level of strength of this connection or the level of correlation depending on their background – being more scientific the latter).
ii. to evaluate the feasibility of five adaptation strategies proposed by the researchers (or their preferences on them)

In most cases, when questioned about the impacts of heat waves in Madrid, participants also mentioned adaptation options when drawing their maps (at step "i."). In these cases, they were asked to confirm those as potential adaptation strategies for the city. A first aggregated map is represented in Figure 10.

During this participatory process, stakeholders have been asked to evaluate the feasibility of five adaptation strategies proposed by the researchers (or their preferences on them) (Table 4). The option are : air conditioning, Heat wave warning systems, parks and forests, trees in streets, green roofs and water bodies. The results have been the following:

Table 4: Stakeholders' perception of selected adaptation measures obtained during teh 22 interviews.

Nr.	A. Air Conditioning	B. HW Warning Plan	C. Parks and forest	D. Trees	E. Green roofs	F. Water bodies (fountains, ponds, lakes)
01	☺	☺	☺	☺	☺	☺
02	☺	☺	☺	☺	☺	☺
03	☺ but….	☺	☺	☺	☺	☺
04	☺ but….	☺	☺	☺	☺	☺ but…
05	☺ but….	☺	☺	☺	☺ but….	☹
06	☺	☺	☺	☺	☺	☺
07	☺but	☺	☺	☺	☺	☺but…
08	☹	☺	☺	☺	☺	☺but…
09	☺ but…	☺	☺	☺	☺ but…	☹ (fountains yes)
10	☹	☺	☺	☺	☺	☹ (fountains yes)
11	☺	☺	☺	☺	☺	☺
12	☹	☺	☺	☺	☺	☹ (fountains yes)
13	☺ but….	☺	☺	☺	☺	☺ but…
14	☹	☺	☺	☺	☺	☺
15	☹	☺	☺	☺	☺	☺
16	☹	☺	☺	☺	☺	☺
17	☹	☺	☺	☺	☺	☺
18	☺ but…	☺	☺	☺	☺	☺ but..
19	☺ but…	☺	☺	☺	☺	☺
20	☺ but…	☺	☺ but…	☺ but…	☺ but…	☺
21	☺ but…	☺	☺	☺	☺	☺ but..
22	☺ but…	☺	☺ but…	☺ but…	☺	☺ but…

(*) Nr. = number of participant. 24 stakeholders have participated in this process from which we have obtained 22 maps.

The table indicates how stakeholders perceived each adaption measures. It clearly appears that air conditioning is not perceived as a good option. Reasons quoted by stakeholders (Table below) are the energy cost and the climate change mitigation problem, its participation in urban heat island effect, its negative effect on respiratory diseases. The expansion of water bodies including fountains does not create a global consensus among participants as it implies a higher consumption of water and increases the vulnerability of the city to drought and water scarcity. Green infrastructures (parks, trees and green roofs) would be globally acceptable for stakeholders. Moreover some stakeholders are sceptic about the potential of green infrastructures to regulate local temperature. Finally the Heat waves waning system is globally well perceived by stakeholders.

The next table shows the specific notes taken during the interviews where other adaptation options were mentioned as well.

Nr. of participant	Adaptation options mentioned
01	She agrees with all the adaptation options proposed by the interviewer and also adds: • Labour reform affecting individuals • Adaptation measures in the working environment • Economic incentives • Social prevention policies/measures
02	He agrees with all the adaptation options proposed by the interviewer and also adds: • Traffic limiting measures • Prevention related to legionella, food-born and vector-born diseases
03	• He mentions traffic limitations but in the map wed o not include the weight only colour in green the already included element "traffic" • Other measures: trees (with volume), green areas, isolation in dwellings • Optimization insulation, ventilation in new urban developments Then, about the adaptation measures proposed by the interviewer: • ALL OK but AC should be accompanied by more investment in R&D and that AC should be placed in shaded areas to decrease outdoor temperature • Green roofs can act as building isolation devises. • Water Bodies decrease outdoor temperature
04	Regarding potential adaptation options he argues: • Air conditioning only in required places (e.g. hospitals?) but it is needed to promote other adaptation measures to avoid dependency on AC. • All green infrastructures are useful • Water bodies and fountains are important but in Madrid water scarcity could be a problem.
05	• AC yes but careful with legionella • Green roofs need high economic investments • Water bodies again with precaution because of the legionella
06	• All OK • They specifically mention HW warning plans, shaded areas and fountains
07	• AC OK but can provoke health problems and high energy consumption • Water bodies OK but it is more effective green strategy. Important fountains
08	• AC should not be considered an adaptation option. They increase heat waves impacts and only help in the decrease of the thermal stress indoor. • Plans are effective in the short term but he wonders which one (a green strategy or a plan) would be more profitable in the long term • GI depend on the water availability • Water bodies, are less realistic. No space, less benefits for recreation and parks provide shadows.
09	• AC yes but under certain conditions: limitation temp and ON times; Sensibilization good practices, high efficiency devices. • The pros and cons of green roofs vs. white roofs must be analysed in terms of maintenance and costs. • Water bodies no. It is not sustainable. Fountains (drinking points) YES.

10	• AC is not a good option. More comfort but more heat emitted outdoors. It is not the solution: better bioclimatic architecture • HW warning plans focused to vulnerable groups • Water bodies (inc. ornamental fountains) no: it is just an aesthetic factor. Fountains (drinking points) YES. Problem with vandalism though.
11	• All yes, drinking points fundamental
12	• AC no a good idea • He argues that HW warning plans might drive psychosis on population e.g. by leaving the bikes • Drinking points fundamental
13	• He argues that storm water collectors and regenerated water network are the adaptation options needed in Madrid to maintain the level of water consumption • AC yes but should be promoted using regenerated water (in testing phase in Madrid) • The same goes for water bodies. Fountains (ornamental) yes but with regenerated water. Now they work with drinking water in closed cycle. • GI yes but maintenance should be guaranteed
14	• AC no, the rest OK • Population education and maintenance of AC equipments are for her fundamental adaptation options
15	He mentions specifically • Sensibilization and water saving campaigns • Demand Planning Then, about the adaptation measures proposed by the interviewer: • AC: NO: high energy and water consumption • Heatwaves warning plan: YES but including drought planning • GI yes because it decreases the infiltration and therefore the sewage system needs • Water bodies YES: drinking fountains, more access to water and to recreational activities
16	All his map is about adaptation options including: • UHI modeling • CC modeling • Real proposals (simulations) • Bioclimatic panning • Energy efficiency measures About the Adaptation measures proposed: • AC: NO. The passive measures are enough. AC can lead to energy poverty • HW warning plan: should include pollution warnings. It is critical • GI and WB OK
17	• Green façades • Green roofs • Economic incentives • Research • Public investment • Private investment Regarding the options proposed by the interviewer: • AC: NO. Increases outdoor heat emissions • The rest: OK

18	• HW warning plans are the only measure of adaptation that he mentions (they decrease mortality and arsons) Regarding the options proposed by the interviewer: ALL YES • AC yes but more respiratory diseases • Parks yes since they decrease the UHI effect • Trees provide shadows • Green roofs YES: color, energy efficiency and more thermal isolation (also provided by double glass windows) • Water bodies YES but the effect is extremely local and provides more aesthetic services than thermal comfort
19	He mentions: • Educational campaigns: as they could increase self caring and social awareness • The warning duration: he believes that if they were longer, the affected people would be less Regarding the options proposed by the interviewer: ALL YES but AC requires further research
20	• They mention information and knowledge as adaptation measures that can support the development of local adaptation infrastructures and services, the adaptation of the health system and increased awareness in the population through also a HW warning system. • They do not point it as an adaptation measure but they also mention green areas Regarding the options proposed by the interviewer: ALL OK but: • AC has to be used rationally as a last resource because of the high energy consumption • Green infrastructures (trees, parks and green roofs) can lead to maladaptations due to an increase in water consumption • Water bodies OK: they raise the importance of more street water sprays and more shadow devises.
21	She mentions: • Information and awareness • Streets watering • Green areas Regarding the options proposed by the interviewer: • AC yes but secondary effects • Water bodies yes but they can spread legionella
22	• Prevention can decrease social vulnerability determinants by the early identification of social services, information campaigns, exposition reduction activities (e.g. day centres transfer of elderly) • Health services awareness • Information campaigns • Green roofs • Appropriate materials • Urban planning • Green areas • Drinking Water fountains • Building regulations • Economic subsidies

Regarding the options proposed by the interviewer:

- AC yes but only in special cases where there is high vulnerability. High energy consumption and outdoor temp increase
- HW warning plan yes. Need of human and economic resources
- Parks/urban forests: yes but limited because most of the exposition occurs indoors
- Trees: yes but according to the interviewee it is not proven that they can reduce outdoor temp (although this contrasts with other expert opinions collected in these interviews)
- Green roofs: yes because of the energy consumption reduction
- Water bodies: yes but only in particular locations. Madrid suffers chronic droughts and water scarcity.

- How you think the participatory process in your case could be/have been improved?

As all participatory process it is limited by the willingness of identified stakeholders to participate. We conducted 24 interviews which is a quite reasonable number of interviews. Increasing the number of stakeholders per se is not an objective since it can produce redundancy. Redundancy is an important issue since the FCM process is a complex process from the selection of the stakeholders to the digitisation of interviews in software[5] and can just increase the cost of processing. Indeed we obtained 22 maps since some stakeholders have performed the mapping together to avoid redundancy of maps. Diversity of stakeholders is an important index to evaluate the process. Figure 6 and Figure 7 illustrate this diversity. We obtain a balance between academic and non-academic stakeholders and participants are from different sectors (health, water, etc).

- Any novel (use of) participatory methods observed in the case studies

The novelty for the case study heat and health for Madrid comes from the combination of FCM (participatory method) with CBA and HIA.

To analyse the performance of different adaptation options, FCM method is performed. This is done through a scenario building application. It is in fact one of the most interesting though not fully exploited applications of FCM. (Jetter and Kok, 2014; Kok, 2009) However, scenarios cannot be used for predictions as if deterministic outcomes. In this line, arguably, they do not offer sufficient information about the magnitude of the efforts in terms of policy actions. However, what such scenarios provide are “alternative and often competing ideas on which it [the future] may unfold” (Jetter and Kok, 2014, p.11), being great policy tools.

[5] There are various software applications which use these or similar formulas and which have been programmed to facilitate the building, execution and analysis of the dynamics of FCMs. See e.g. Jose, A., Contreras, J., 2010. The FCM Designer Tool, in: Glykas, M. (Ed.), Fuzzy Cognitive Maps: Advances in Theory, Methodologies, Tools and Applications. Springer Berlin Heidelberg, pp. 71-87.

The scenarios that are built based on a modelled network. They can therefore be interpreted as what might happen in the future if alternative sets of policy options are used. This is done in the context of the collective knowledge that best illustrates the complexity of the system (i.e. taking into account the individual maps provided by the stakeholders during the participatory process). The scenario tool of the FCM consists in changing the influence of one of the concept nodes, like heat health warning system (HHWS) if we want to simulate a policy promoting the efficiency of a HHWS. The simulation tools of the FCM returns a percentage change in the rest of the concepts of the map (like mortality/morbidity). This helps to understand and quantify how much the concept nodes of a complex casual maps will change when one of them changes.

Up to now, we have aggregated these 22 individual models and got an aggregated map which will be the base to simulate scenarios. These scenarios (or policy options or a combination of them) will help to prioritise based on semi-quantitative indicators different adaptation options and identify potential unintended positive or negative impacts. Indeed, the FCM is a semi quantitative tool, it does not allow to directly monetize these changes in terms of costs and benefits. We believe that the simulation tool of the FCM can help to test the robustness of a CBA, i.e. make sure that the CBA has identified and estimated the most important costs and benefits, those that stakeholders/participants have mapped.

Further steps remain to be done before simulating scenarios. A first one is to simplify and reduce the number of concept nodes (168 in Figure 10) in order to obtain clear information change without losing relevant concepts. Then the simulation tool can be used to test the robustness of the CBA, once costs and benefits are estimated.

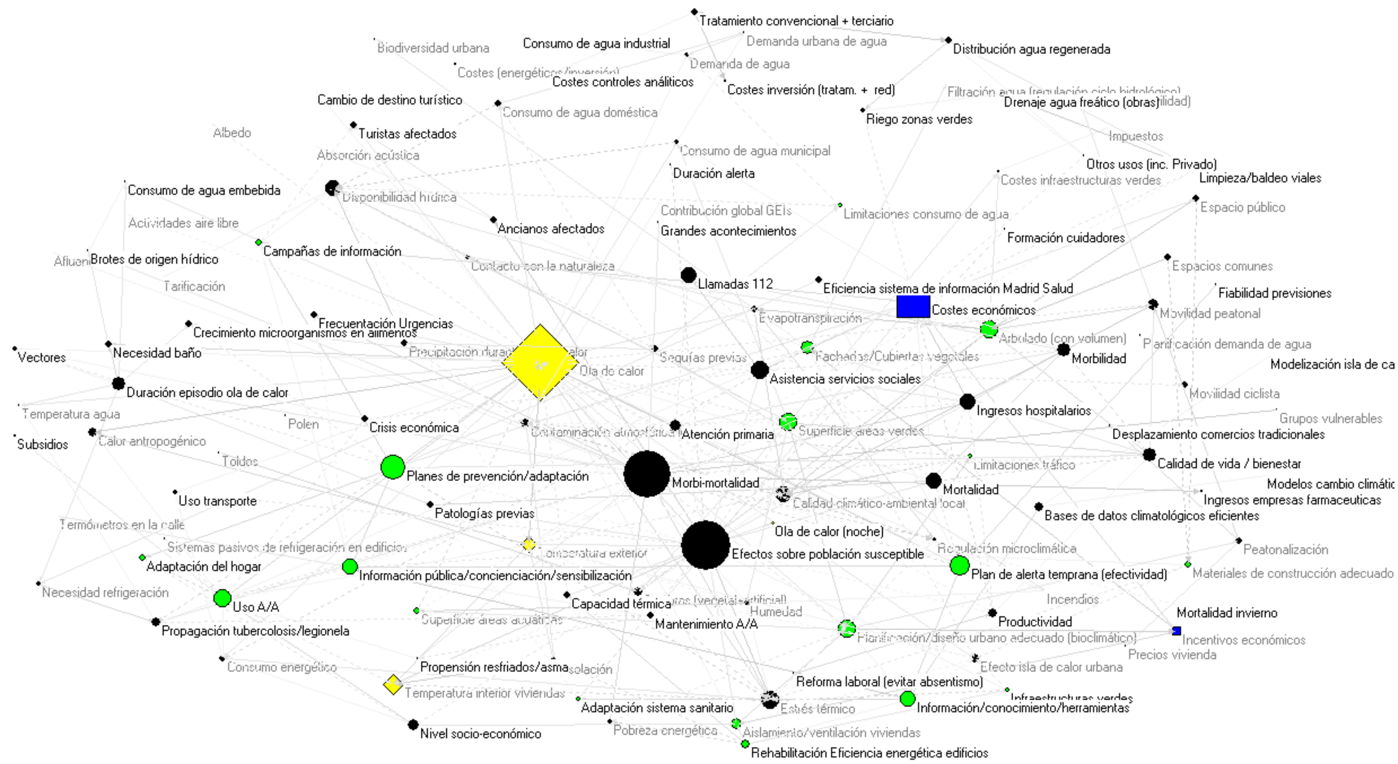


Figure 10: Aggregated map: 168 concepts in 4 groups: adaptation (green), costs (blue), temperature related (yellow) and general (black).

Climate Change Adaptation Measures and Strategies

a) Adaptation Measures under analysis in your case study

(Please identify your Adaptation Measures considered in this case-study and provide a short description of each)

Table x provides an overview of the potential adaptation measures considered in the water policy analysis. The measures were evaluated with the participation of the stakeholders by means of a Focus Group. Four measures were selected and will be further evaluated by citizens/stakeholder participation and cost-benefit analysis.

Table 5 Summary of the adaptation measures considered in the water policy analysis

Type of policy	Quantify the results of policy
Supply management policies	Water allocation for environmental and consumptive uses
	Reuse of urban water
	Reduction of water allocation
	Increase water supply
	Increase supply efficiency
Demand management policies	Reduction of per-capita or per-hectare water use
	Water rights exchange programs
	Increase resource efficiency

Table 6: Summary of the adaptation measures considered in the heat and health case study

#	Type of Policy	Quantify the results of policy
1	Health policies	Heat-wave warning system HWWS: no consensus about the alert threshold
2	Green infrastructures	Green roofs
3		
4	Water demand	Water fountains
5	Technological adaptation	Air conditioning

Adaptation Measure(s):

Reuse of urban water
Water rights exchange programmes
Heat-health warning systems
Green infrastructures: trees in the street, parks, green roofs

Short description for each Adaptation Measure (Máx 50 words):

Reuse of urban water. Reusing and recycling alternative water supplies is a key part of reducing the pressure on our water resources and the environment. This measure is very important in urban areas due to projected increase in population. This measure has to include a technical evaluation of the level of risk, account end use, and resource and energy requirements.

Water rights exchange programmes. Water exchange among different users is a mechanism that ensures water use to the sector that needs it and values it the most. Water exchange programmes may make water available for new uses, such as increasing stream flows, providing irrigation in urban parks and gardens, and providing water for urban development. Although exchange programmes may differ, the common goal is to move water to where it is needed most.

A HWWS consists in an alert system which provides information to citizens on the grade of risk relative to heat. It is defined around some thresholds of alert (36.5C and 38.5C in Madrid) and duration of the heat waves. The definition of the threshold, i.e. the temperature above which death increases significantly and sharply is controversial and not harmonized between the different institutions (national versus local institutions)

Green infrastructures consists in implementing areas to refresh and mitigate the heat like parks and lines of trees in the street. A challenging issue lies in the heat island effect estimation (mitigation of heat) and in the trade-offs with allergies.

Water demand. It consists in supplying public water to citizens with fountains. A trade-off appears with water demand management proposed: water fountains have been proposed by some interviewed stakeholders which challenges the reduction of per capita water uses.

b) Adaptation Measures selection and data availability prior to BASE

(Please describe how and why where these specific measures selected for further research and analysis under BASE and what is the baseline data already available for each specific adaptation measure. Máx 500 words)

Heat and Health case study:

The health related measures have been proposed by stakeholders or suggested by the researchers during the interviews. A process of data collection to estimate costs and benefits of these measures is ongoing.

c) Full description of Adaptation Measures

(Please provide a full description on each of the Adaptation Measures regarding these 21 leading questions under. If more than one Adaptation Measure please copy paste the structure provided.)

Process

Would, or at which part would, institutions and private stakeholders implement the measure autonomously to adapt to climate change (Adaptive capacity)?

(fill with your answer)

Does the measure initiate further activities for adaptation to climate change? (Y/N)
If Yes, please name which

Does adaptation aim for flexibility and reflexivity (i.e. the ability to change as CC and other factors develop)? (Y/N)

Is the measure effective under different climate scenarios and different socio-economic scenarios? (Y/N)

Is the adaptation measure iterative? (Y/N)

Does the measure contribute to overall sustainable development, alleviate already existing problems and bring benefits for other social, environmental or economic objectives than adaptation (no regret measures)? (Y/N)

Please describe briefly how

(fill with your answer)

Can adjustments be made later if conditions change again or if changes are different from those expected today? (Y/N)

Outcome

Relevance and effectiveness of adaptation measures

How important is the climate change threat addressed by the measure? What economic values, ecosystem functions and socio-cultural values are at stake, and to what extent are they affected by climate change impacts? Is there an indication of overriding public interest, e.g. critical infrastructures, public health ?

(fill with your answer)

What portion of the targeted potential damages can be avoided by implementing the measure? (0-100%)

Efficiency

How high are the benefits of the measure relative to the costs? Are the costs justified by the benefits(Please refer to results of economic evaluation in chapter 5)

(fill with your answer)

What are the costs of the administrative implementation of the measure? Are there potential

(fill with your answer)

funding under the umbrella of other European policies (eg. CAP/Cohesion policy)

Does the measure give an incentive for innovation to different actors (e.g. SMEs) / can it deliver a competitive advantage for the local economy? (Y/N)

Does the measure have effects on employment? (Y/N)

How long is the time-lag between implementation of the adaptation measure and the effect of the measure? ______

What is the timeframe during which the measure will have an effect?
____

Does the measure create synergies with mitigation (i.e. reduce GHG emissions or enhance GHG sequestration)? (Y/N)

Does the measure alleviate or exacerbate other environmental pressures? (Explain briefly)

(fill with your answer)

Equity

What are the impacts on different social or economic groups, are there expected impacts on

(fill with your answer)

particularly vulnerable groups? (distributional impact)

Does the measure enhance well-being and quality of life (e.g. in the urban environment)? (Y/N)

Impacts, Costs and Benefits of Adaptation measures

(This section of the CSLD follows the Economic Assessment Steps put forward by UFZ and thoroughly described in D4.1, chapter 4. Please check D4.1 for any doubts or questions. In case of duplication of information with previous sections of the CSLD feel free to copy paste.) For more detailed guidance (incl. two examples) please see the above mentioned chapter 4 of D4.1. Please do not hesitate to contact volker.meyer@ufz.de, oliver.gebhardt@ufz or Filipe Alves if you have questions about how to fill out this section.

Step 1 – Preliminary Risk Assessment and identification of adaptation tipping points (max 1500 words)

(Some of these questions might be already answered in section 1 – if so, just copy & paste)

What is the climate change related problem/risk you would like to reduce by adaptation?

- Which problems already exist, what is/are the current risk/s?
  Extreme temperatures and water scarcity
  Climate in the Madrid region is characterized by having hot and dry summers and cool winters. Temperatures show a very sharp gradient following a similar pattern of rainfall. The hottest month is August and January the coldest. Summer becomes hot, so are long and cold winters, warm summers and spring and autumn are short seasons and irregular but very marked. Typically temperatures are higher in cities than on the outskirts and this difference increases on stable periods for the presence of the anticyclone, giving rise to the phenomenon called urban heat island, an atmospheric situation that occurs in big cities and involves rapid increase in temperature form the outskirts to the city centre, where buildings and asphalt off the heat accumulated during the day. One of the most outstanding characteristics of the Madrid climate is the irregularity of the inter-annual rainfall.
- Which assets and sectors are at risk under current climate variability?
  Health and Social Policies, Biodiversity & Ecosystems, Disaster management among others.
- Which adaptation or protection measures are already in place? (refer to typology of measures in D6.1, table 2)
  Non-structural: Awareness raising, Disaster response management, Risk transfer tools.
  Structural: Water conservation, Water saving measures, Ground water management, Water technology, Measures to minimise exposure to diseases
- How do these risks presumably change due to climate and socio-economic change?
  All of the above mentioned risks are taking place. Climate Change will increase their effects.
- What are the main drivers, impacts and affected sectors (refer to BASE impact and sector categories, see also Table 1 of D6.1)
  Water Management, Human health, Agriculture, Human settlements and infrastructure, Biodiversity and ecosystems.
- Which climate and socio-economic scenarios are used?
  Two choices: (1) Representative Concentration Pathway RCP 8.5 combined with Shared Socioeconomic Pathway SSP 5, which represent a conventional high development, and (2) RCP 4.5 combined with SSP2, which giving the image of a world more concerned with the environmental problems.

Which adaptation tipping points can be identified?

The adaptation pathway approach is not applied for the Tagus case study.

- Can adaptation tipping points, critical levels for adaptation, be defined for this current strategy? (=when objectives are not met anymore due to changes)
  Refer to otherwise expand on Table 3 of D6.1
- When (roughly) will these critical levels be reached due to climate change or socio-economic change
- Give appropriate period (2015-2030, 2030-2050, after 2050) for each considered combination of climate and socio-economic scenario.

Step 2 – Identification of Adaptation Measure and Adaptation Pathways (max 1500 words)

(some of these questions might be already answered in section 4 – if so, just copy & paste)

What are the alternative adaptation measures?

- What are the primary and secondary objectives of adaptation?
  The main objective of adaptation is to reduce the vulnerability of society to the effect of water scarcity and high temperatures, with special attention to the most disadvantaged. Water is a limited resource that supports human activities. Climate change is only one of many pressures faced by water management today and in the future. However climate change is a very significant pressure since it has a direct impact on all aspects of water for people. A range of adverse impacts include reduced water availability and more frequent extreme events, such as droughts. These negative impacts may put water resources management, certainly at the level of individual land managers and regions, at significant risk under uncertain conditions. This uncertainty is especially relevant for the water sector because it links to health, agriculture and food security, industry and energy, ecosystems, cities, and culture. Climate change comes in conjunction with high development pressure and increasing populations which poses a major challenge on water management.

- What are potential measures to meet these objectives? (refer to typology of measures in D6.1, table 2)
  Reuse of urban water
  Water rights exchange programmes
  Greening the city: green roofs
  Well defined Heat Health Warning System
- What is your baseline option (the “business-as-usual”-option)?
  Climate change is only one of many pressures faced by water and health management today and in the future. Some of the measures used to cope with current hazards have yet an exceptional character and may not be enough for future scenarios.
- What is the ambition level of this baseline strategy? : Maintaining current risk levels or current protection levels (implying with CC risks may increase)?

Most of the stakeholders try to maintain current protection levels seen from a single sector point of view. The case study analyses trade-offs and synergies between sectors to ensure a more resilient society under future climate conditions.

- Is current backlog of investments for adaptation measures included or excluded?
  All investment options are included.
- Does it include only planned adaptation or also autonomous, non-planned adaptation?
  It includes planned adaptation and changes on behaviour of the population.
- Are there complementary measures? Is it appropriate to bundle these measures?
  All measurements are complementary and studied only considered individually to apply the appropriated methods of analysis.

What are alternative adaptation pathways?

The adaptation pathway approach is not applied for the Tagus case study.

- What is the "sell-by"-date of the measures or bundles of measures? I.e. when will they – under conditions of climate change – not any longer be able to meet the defined objectives?
- What would be alternative measures or bundles of measures at these "tipping points"?

Step 3 - Evaluation Criteria and Method (max 2000 words)

Step 3a Selection of evaluation criteria

Which evaluation criteria should be used?

- What are the relevant positive and negative properties of the measures (costs and benefits) to be considered in the evaluation process (economic, ecological and social effects)? (see D4.1, chapter 4 for examples)
  Water is needed for most of the adaptation measures to cope with climate change in the health sector. Options analysed are the reuse of waste water and the right exchange. The drawbacks of these measures are (1) implementation and maintenance costs and (2) impacts on the ecosystems.

- What is the appropriate unit to measure each of these criteria?
  Several units are used to measure different criteria. Public health has usually used cost-effectiveness analysis (CEA), which estimates the cost of achieving a certain health impact, measured as number of deaths, cases or DALY avoided. The method is used to identify the measure with the highest cost-effectiveness. Cost-benefit analysis (CBA), on the other hand, estimates and compares costs and benefits in monetary terms, in order to identify the

measure with the highest net benefit. Both methods focus on the social costs of implementation, defined as the aggregated opportunity costs incurred by the society if the measure is put in place. The costs of a measure are those associated to the direct implementation of the measure, to the effort needed to improve adaptive capacity (institutional costs such as those related to infrastructures, training, information) and to the resource reallocation, these latter being usually not included as difficult to estimate.

- Is the performance of the adaptation options measured in qualitative, monetary or other quantitative terms?
  The general performance of the adaptation measures is evaluated using qualitative methods. Specific measures are evaluated both in quantitative and semi-quantitative terms using cost benefit analysis and Fuzzy Cognitive Mapping method.

Step 3b Selection of evaluation method(s)

What is the appropriate evaluation method?

- Is it possible to express all relevant cost and benefit criteria in monetary terms?
  (→ cost-benefit analysis)
  There are generally approved in literature methods to correlate the HIA to monetary figures, thus a Cost-Benefit analysis is used for the health sector.
- Is it possible to express the positive effect (objective) by a single non-monetary indicator?
  (→ cost-effectiveness analysis)
- Are there several relevant criteria which cannot or cannot easily be expressed in monetary terms?
  (→ multi-criteria analysis, PCBA)
  There are generally approved in literature methods to correlate the HIA to monetary figures, thus a Cost-Benefit analysis is used for the health sector.

Step 3c Weighting of evaluation criteria (applicable only to multi-criteria analysis)

What are the preferences of stakeholders regarding the different evaluation criteria?

- Are there different stakeholder groups with varying preferences regarding the evaluation criteria?

- Which weight do stakeholders and/or decision makers attach to a substantial change in the performance of the adaptation options regarding each evaluation criterion?
  (see D4.1, chapter 4.10.2 for guidance for the Swing-Weight method)
  During the participatory process developed to implement the FCM, stakeholders have been asked to evaluate the feasibility of five adaptation strategies proposed by the researchers or their preferences on them (see chapter 4, section D for a more detailed report). They were asked to say if a specific measure was positive or negative, and had the possibility to express objections (yes/no/yes but).

Step 4 - Data collection (max 2000 words)

What are the costs and what are the benefits of the alternative adaptation options?

- What potential data sources are available, including damage & impact assessment methods or existing CBA studies on adaptation measures?
  Water: Ministry of Health, Water Quality Department, River Basin Authority, CEDEX (Centre for Hydrographic Studies).
  Health: The main data source is the Health Ministry through the Health and Climate Change Observatory. Additional data sources are the Regional Government of Madrid and the Carlos III Health Institute.
- In the case of health, the benefits of a heat-health warning system (HHWS) are estimated based on an epidemiologic relationship relating climate factors and confounders (pollution, noise, etc) to mortality. Measuring benefits of HHWS in terms of avoided death means to firstly estimate the effectiveness of a HHWS. The task is a very challenging one; Toolo et al. 2013 indicates that only 7 papers performed a measure of effectiveness but none of them define a causal relationship and only 1 paper presents a CBA. Indeed isolating the HHWS is a very complicated and controversial issue due to comparability of heat waves, social changes, learning effects, etc. We will estimate the impacts of having an efficient HHWS with a statistical epidemiologic method, based on data specific to Madrid. This method will give us the avoided death thanks to an efficient HHWS. The analysis will be conducted under climate change scenarios. The estimation of the benefits of green infrastructure is challenging in determining the cooling effect of the measures and their capacity to reduce the urban heat island effect. If no relevant data sources are available and modelling cannot be undertaken: Which experts can estimate proxies for assessing the performance of measures regarding the respective criterion?

Alongside with the modelling of the future climate data of the estimations of the effectiveness of adaptation measures are obtained from literature. See the references chapter.

- How do the adaptation options perform with regard to each of the cost and benefit criteria selected in step 3a?

There are no CBA analysis for green roof that would correspond to a Mediterranean climate with continental influence like Madrid (classification of Köppen). We therefore estimated the CBA, the potential benefits of green roof is linked to the climate change.

Green roofs generated an exhaustive list of services and disservices, Table 7. We adapted this list form Berndtsson, 2010; Oberndorfer et al., 2007; Wang et al., 2014). For the CBA on green roof, we modelled the benefits of **energy saving** due to a reduced necessity of indoor cooling and the **water retention services**. Urban Heat island reduction effect is qualitatively discussed. We can distinguish the private and public services. A public services is a services that follows the definition of a public good (non-rivalry and non-excludability in its use). By intangible services, we refer to services which valuation cannot be done through a market value. Tangible means that the valuation units is derived from a market value.

Table 7 List of costs and benfits of adaptation measures

Adaptation measures	Cost	Benefits	Modelled	Private / Public	Physical units of the services	Tangible/In tangible
Heat-Health Warning System	Implementation , personal cost. The variable cost is a function of the number of days of alert	Avoided mortality attributable to heat wave	Yes	Public	Avoided mortality	Tangible
Green roofs	Implementation + maintenance	Energy Saving	Yes	Private	Kilowatt hour	Tangible
		Water retention	Yes	Private/ Public	Cubic meter	Tangible
		Carbon footprint reduction	Yes	Public	CO2	Tangible
		Health	Yes	Public	Avoided mortality	Tangible
		Urban Heat Island reduction	Yes	Public	Temperatu re	Intangible
		Habitat for biodiversity	Discussed	Public	-	Intangible
		Air quality (positive and negative services)	No	Public	-	Intangible
		Sonic services: noise reduction, pleasant noise	No	Public	-	Intangible
		Aesthetic	No	Public	-	Intangible

Below we present in section A, the green roof CBA with subsections for the costs and selected benefits and in a section B the CBA for the Heat Health Warning system of Madrid.

A – Green roofs costs and benefits

1. **Potential of green roof in Madrid and its costs**:

Sproul et al. (2014) give cost estimates for 22 case studies in the US. The maintenance cost is 2.29€/m2/year. The lowest cost of the first installation is 85€/m2, the median is 135€/m2 and the maximum 178€/m2. Obermdorfer et al. (2007) gives range of 80/240 €/m2 for extensive roofs.

As noted in Obermdorfer et al. (2007) water needs for green roof are negligible as much as plant species are adapted to the local climate. We do not consider irrigation in the maintenance cost. We consider a 30 years lifespan for the green roof and a renovation of the roof after the age. For traditional roofs we use a 20 years lifespan. We use data collected from CYPE Ingenieros, the Catalonia Institute of Construction Technology – Itec and two manufacturer of building products DANASO and TEXSA for green and traditional roofs. We compute the additional cost of green roofs (Table 8)

Table 8. Unit additional cost of green roof installation

€/m2	Low	Average	High
New green roof	26	36.5	47
Existing green roof	51	164	277
Maintenance/year	1.3	2.6	4

We consider that green roof would replace already the installed conventional roofs and simulate **4 scenarios of green roofs coverage** over the buildings area of Madrid: **5%, 20%, 50% and 100%.**

Five different discount rates are considered for the period 2020-2100. We obtain the following discounted costs of transformation of existing roofs, for the average unit cost and under the socio-economic scenarios SSP2 and SSP5.

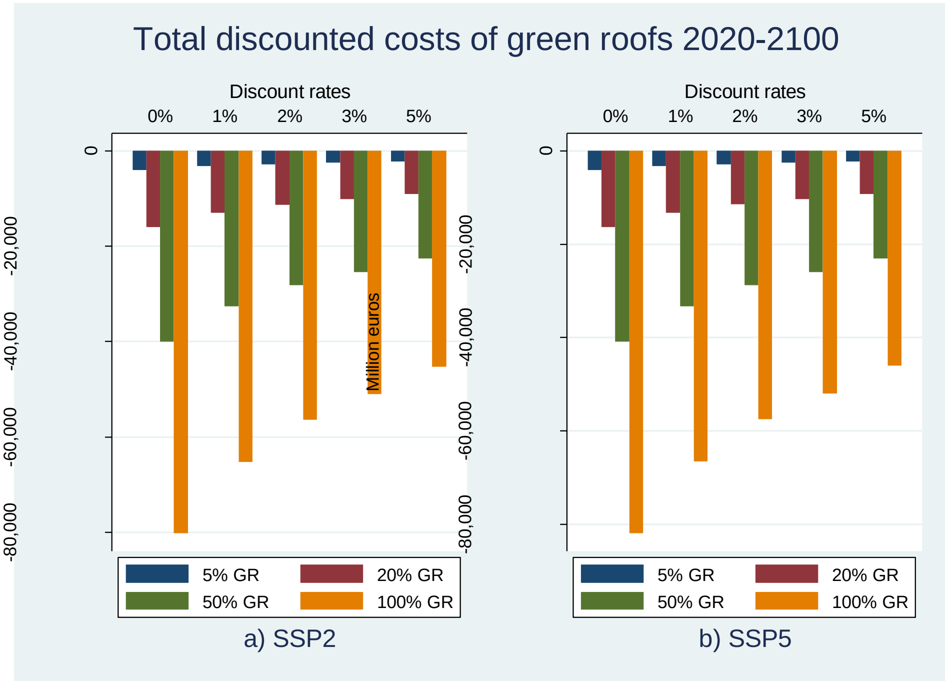


Figure 11: Discounted additional total costs of green roofs in Madrid

The following graph illustrates the difference between the 2 socio-economic scenarios, SSP2 and SSP5 in the range of costs. Given that the different green roof coverage scenarios are linear, we represent only the 5% coverage scenario and give the range of estimated costs (low, average and high).

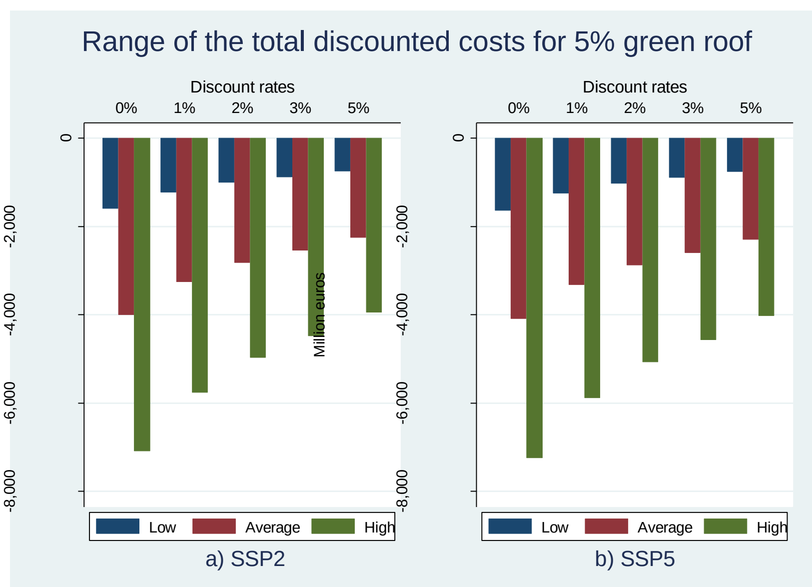


Figure 12: Range of estimates of discounted additional costs of green roofs for a 5% coverage

The investment consists in a fixed initial cost and a flow of discounted maintenance costs. Table 9 gives this repartition for the 5% roof coverage scenario, the other scenarios of green roof coverage (20%, 50%

and 100%) are proportional to the 5% coverage scenario. We see that over 2020-2100, the maintenance cost is higher than the initial costs until the 3% discount rate for average values

Table 9: Discounted initial and maintenance costs for 5% green roof coverage, under SSP2

	Total Initial cost , million euros			**Discounted total maintenance cost over 2020-2100*, million euros**		
Discount rate	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
0%	279	898	1518	524	1107	2029
1%	279	898	1518	338	734	1366
2%	279	898	1518	230	514	971
3%	279	898	1518	164	378	725
5%	279	898	1518	98	234	458

*:includes the renewing of the roof every 30 years

These estimates assume that there is no economies of scales. With economies of scales we could expect that the costs of construction would decrease as adoption of green roofs becomes larger.

2. Contribution to urban heat island effect reduction

The phenomenon of urban heat island reflects the fact that urban areas are warmer than the surrounding rural areas. In the absence of sufficient stored moisture, solar energy is to heat artificial impervious surfaces instead of being naturally used to evaporate water as it occurs in rural and open areas. This evaporation creates a cooling effect and thereby reduces the temperature of the surroundings. In cities, others source of warming originates from anthropogenic activities like among others the use of energy for transportation, cooling buildings, lighting which exacerbates the urban heat island effect. The use air conditioning use in a city would contribute up to 2ºC in urban heat island (Salamanca et al., 2012; Tremeac et al., 2012; Wen and Lian, 2009). In Madrid, the urban heat island effect reaches the 5-6ºC (Yagüe and Zurita, 1991) and is not spatially uniform over the city (Fabrizi et al., 2011). Cooling cities with albedo changes or vegetation is an adaptation measures whose cooling potential depends upon factors like the local climate, the extension and the characteristics of cool/green roofs (Santamouris, 2014)

The effectiveness of green infrastructure solutions in reducing urban heat island, i.e. changes in albedo, planting curbside with trees, installing green roofs and green walls are studied at experimental micro scales (Alexandri and Jones, 2008, 2007; Kumar and Kaushik, 2005) and at simulated meso scales (Bass et al., 2002; Georgescu et al., 2014; Rosenzweig et al., 2006; Salamanca et al., 2012; Susca et al., 2011; Taha, 1999). At meso scale, the urban heat island mitigation depends on the scenario of adaptation: only single green infrastructure measures[6] and others a bundle of measures (Table 10). The higher

[6] Although changes in albedo is a green infrastructure measures we included it in this category as it also represents the simulated effect of green roof installation.

mitigation effect is obtained with the mixed of adaptation measures (Rosenzweig et al., 2006; Salamanca et al., 2012; Taha, 1999) and when the soil moisture is artificial increased (Bass et al., 2002).

In a climate change context, Georgescu et al. (2014) simulate the UHI reduction for six US states and found an UHI reduction between 0.2 and 1.2ºC from green roofs.

Table 10: Urban heat island mitigation from adaptation measures

					UNIT: Degree Celsius							
					Single adaptation mesaures					Mixed Adaptation Measures		
Authors	**year**	**Country**	**City**	**Coverage**	**Green Roof**	**Irrigated green roof**	**Albedo change (Light roof)**	**Planting curbside with trees**	**Open space planting**	**Ecological infrastructures: green roof, trees, grass**	**Air Cond. off,Insulation, Albedo**	**Plant, Albedo**
Bass et al.	2003	Canada	Toronto	5% total land area of the city	0.5	1 to 2	NC	NC	NC	NC	NC	NC
Rosenzweig et al.	2006	US	New York city	100% of available areas	0.33	NC	0.275	0.22	0.11	0.66	NC	NC
				50% of available areas	0.154	NC	0.16	0.12	0.06	0.70	NC	NC
Salamanca et al.	2012	Spain	Madrid	100%	NC	NC	NC	NC	NC	NC	1 to 2	1 to 2
Taha et al.	1999	US	Los Angeles	100%	NC	NC	NC	NC	NC	NC	NC	1.5
			Chicago		NC	NC	NC	NC	NC	NC	NC	1
			Atlanta		NC	NC	NC	NC	NC	NC	NC	1
			Washington		NC	NC	NC	NC	NC	NC	NC	0.5
			Philadelphia		NC	NC	NC	NC	NC	NC	NC	1
			New York		NC	NC	NC	NC	NC	NC	NC	1
			Houston		NC	NC	NC	NC	NC	NC	NC	1
			Dallas		NC	NC	NC	NC	NC	NC	NC	1
			Phoenix		NC	NC	NC	NC	NC	NC	NC	1
			Miami		NC	NC	NC	NC	NC	NC	NC	0.5
Georgescu et al	2014	US	California	100%	0.24	NC	1.45	NC	NC	NC	NC	NC
			Arizona		0.15	NC	0.47	NC	NC	NC	NC	NC
			Texas		0.46	NC	1.24	NC	NC	NC	NC	NC
			Florida		0.21	NC	0.41	NC	NC	NC	NC	NC
			Mid Atlantic		1.19	NC	1.8	NC	NC	NC	NC	NC
			Chicago/Detroit		0.85	NC	1.37	NC	NC	NC	NC	NC

Based on Table 10 and expert consultation, we extrapolate for the city of Madrid the UHI reduction for different coverage of green roofs. We assume arbitrarily a proportional relation between green roof coverage and UHI mitigation. A critical area of green roof is required to observe a cooling effect at the city scale, we observe that below 50% the temperature reduction is negligible (Table 10).

Table 11: UHI mitigation potential in Madrid

	Green roof coverage			
	100%	**50%**	**20%**	**5%**
Average, ºC	0.30	0.15	0.06	0.015
min, ºC	0.1	0.05	0.02	0.005
max, ºC	0.5	0.25	0.1	0.025

Source: Adapted from Table 10 and expert consultation

Urban heat island makes people in urban areas more exposed to heat waves which would increase heat related mortality (Rey et al., 2009) and also increase the demand of energy for cooling with air conditioning which in turns increase the outdoor temperature. We therefore consider in this analysis that the urban heat island reduction from green roof impacts urban health and the demand of energy for cooling.

3. Benefits of green roofs: energy consumption reduction

Energy consumption reduction obtained from green roof originates from better insulation of the building which results in lower electricity demand for cooling and from a reduction of the number of days where air conditioning is used due to UHI reduction obtained from green roofs.

Green roofs by providing a better insulation of building generate energy savings for the building (Castleton et al., 2010). Although the savings are decreasing with the distance to the roof (Saiz et al., 2006), an average rate energy saving can be calculated. In Madrid, Saiz et al. (2006) shows that green roof reduced by 6% the cooling load in summer on an 8-story residential building. Salamanca et al. (2012) find a 4.82% and a 3.59% energy consumption reduction for albedo modification and insulation of the roof in Madrid and with an indoor temperature of 25ºC maintained by air conditioning.

A reduction of outdoor temperature due to green roof's cooling effect would reduce the number of days where air conditioning is used. The Spanish regulation on thermal facilities in buildings recommend a threshold of 28ºC for outdoor temperature and a target indoor temperature of 25ºC. With these thresholds, Izquierdo et al. (2011) derived the energy load for air conditioning for residential uses in Madrid Community. For the 38% of residential buildings equipped with air conditioning in Madrid and adjusting for migration during summer holidays they found that the electricity consumed by air conditioning units accounted for about 6.7% of the total consumption of electricity, or 920 KWh per home equipped with air conditioning. We use the average of energy consumption and price over 2009-2013 for residential units in Madrid and (Madrid Municipality, 2015; Red Eléctrica de España, 2014) to estimate and value these two sources of energy. We use the outdoor temperature of 28ºC as a threshold to compute the number of days where air conditioning is used and the number is days where the urban heat island reduction contribute in not using air conditioning.

Table 12: Total discounted benefits in million euros of energy savings services from green roofs, for 2020-2100

Climate change scenarios		Green roof coverage	Discount rates 0%	1%	2%	3%	5%
	SSP2 and Rcp45	5%	12.3 (9.2-15.7)	8.8 (6.4-11.1)	6.6 (4.7-8.3)	5.1 (3.6-6.5)	3.4 (2.3-4.4)
		20%	43.6 (28.4-65.8)	30.6 (19.8-46.4)	22.7 (14.6-34.4)	17.6 (11.2-26.7)	11.8 (7.3-17.9)
		50%	114.2 (71.5-150.5)	79.6 (49.8-105.3)	58.5 (36.6-77.5)	45 (28.2-59.7)	29.8 (18.7-39.5)
		100%	218.5 (145.1-289.2)	152.3 (100.8-201.6)	111.8 (73.8-148.1)	86 (56.6-113.9)	56.8 (37.4-75.4)
	SSP5 and Rcp85	5%	13 (8.5-16.9)	8.8 (5.6-11.5)	6.3 (3.9-8.3)	4.8 (2.9-6.3)	3.1 (1.8-4.2)
		20%	48.1 (31.4-66..8)	32.5 (21.2-45.5)	23.2 (15.1-32.8)	17.5 (11.4-24.8)	11.2 (7.4-16.2)
		50%	119 (80-156.4)	81 (54.106.8)	58.3 (38.6-77.2)	44.2 (29-58.7)	28.8 (18.6-38.4)
		100%	232.5 (157.8-310.5)	157.9 (106.8-211.5)	113.6 (76.4-152.5)	86 (57.6-115.6)	55.9 (37.2-75.4)

Low and high values in parentheses
Unit: million euro

The discounted benefits from energy savings services delivered by green roofs are increasing with the coverage of green roof. For a discount rate of 2%, it varies from 6.6 million euros for a 5% of green roof coverage under SSP2 and Rcp4.5 to 113.6 million euros for a full coverage in Rcp8.5 and SSP5.

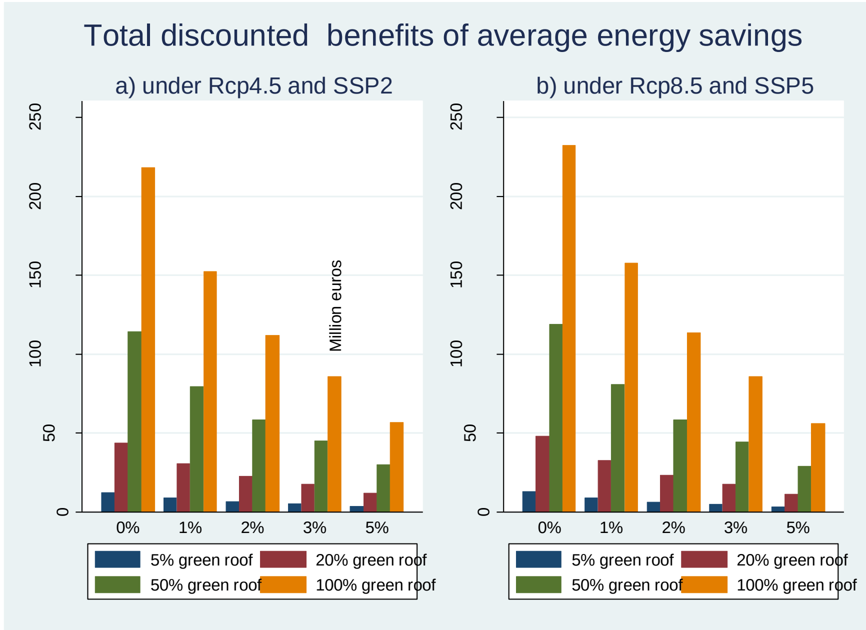


Figure 13: Total discounted benefits of average energy consumption reduction, 2020-2100

The difference of energy saving between the two Rcps depends on the number of days where the AC is on, i.e. whenever the maximum of the monthly average temperature exceeds 28ºC. Then, we can see that the difference in total energy savings between the socio-climatic scenario is not very high (Table 12).

1. Benefits of green roofs : Carbon footprint reduction

The carbon footprint is reduced with green roof by the sequestration of CO_2 by the plants and by the reduction of the consumption of electricity used for air conditioning.

Green roofs sequester carbon in plants and soils. During photosynthesis carbon is removed from the atmosphere and is stored into the plants. Part of the carbon is also transferred to the soil as a natural process to increase soil organic matter necessary to the plant growth. Getter et al. (2009) and Whittinghill et al. (2014) decomposed carbon sequestration of a green roof as carbon sequestrated in the aboveground biomass, in the root biomass and in the substrate organic matter. In the urban landscape, carbon sequestration capacity of green has received less attention than other natural support like street trees. Wang et al (2014) reviewed the literature for trees. Getter et al. (2009) study with a 6 years experiments the carbon sequestration potential of extensive green roofs in Michigan and Maryland. They found an average carbon sequestration capacity of 162 gC/m^2 with a large variability: The site with the minimum carbon sequestration registered 73 gC/m^2 and the maximum observed carbon sequestration is 276 gC/m^2.

Avoided emissions uses of electricity for air conditioning reduces CO_2 emissions. The CO_2 footprint of electricity production depends on the resources used to produce electricity. In Spain or the period 2009-

2013, the carbon footprint is estimated on average at 0.250 kg CO_2/Kwh, with low value of 0.21 kg CO_2/Kwh observed in 2010 and a high value of 0.30 kg CO_2/Kwh in 2012 (Red Eléctrica de España, 2013).

Table 13: Total discounted benefits of CO2 emission reduction services from green roofs, for 2020-2100

Climate change scenarios		Green roof coverage	Discount rates: 0%	1%	2%	3%	5%
	SSP2 and Rcp45	**5%**	5.9 (1.8-28.4)	3.8 (1.1-18.1)	2.5 (0.8-12.2)	1.8 (0.5-8.6)	1.1 (0.3-5)
		20%	23.1 (6.8-114.9)	14.8 (4.3-73.2)	10 (2.9-49.2)	7.1 (2.1-34.8)	4.1 (1.2-20.1)
		50%	58.5 (16.9-283.5)	37.3 (11.1-181.3)	25.2 (7.4-121.1)	17.8 (5.2-85.4)	10.4 (3-49.4)
		100%	116 (31-563.7)	74 (21.7-358.4)	49.8 (14.6-240.4)	35.4 (10.4-170)	20.6 (6.1-98)
	SSP5 and Rcp85	**5%**	6.2 (1.8-29.8)	3.9 (1.2-18.6)	2.6 (0.8-12.6)	1.9 (0.5-8.9)	1.1 (0.3-5.1)
		20%	24.3 (7.1-118.9)	15.4 (4.5-75.2)	10.3 (3-50.3)	7.3 (2.1-35.4)	4.2 (1.2-20.3)
		50%	60.6 (17.9-293.6)	38.5 (11.4-185.8)	25.8 (7.6-124.2)	18.2 (5.4-87.5)	10.6 (3.1-50.2)
		100%	120.7 (35.7-586.7)	76.6 (22.6-371.6)	51.3 (15.2-248.1)	36.3 (10.7-174.8)	21 (6.2-100.2)

Low and high values in parentheses
Unit: million euro

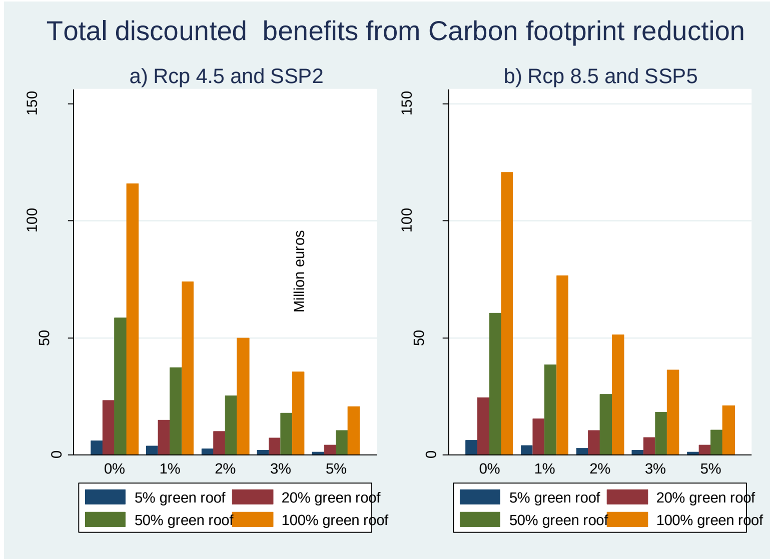


Figure 14: Total discounted benefits of carbon footprint reduction

2. Benefits of green roof: Health

High temperature in summer may result an excessive premature death of the susceptible population (Kovats and Hajat, 2008). An increase of extreme temperature as well as longer heat wave observed with climate change would exacerbate premature death (McMichael et al., 2006; Peng et al., 2011; Wu et al., 2014). In cities, this increased mortality is boosted by the urban heat island effect. (Rey et al., 2009). Adaptation measures to heat waves are articulated around the development of effective heat health warning systems (Ebi et al., 2004; Kovats and Ebi, 2006; Lowe et al., 2011; Michelozzi et al., 2010; Pascal et al., 2006; Toloo et al., 2013). In the section, we are interested in testing the effect on mortality of mitigating the outdoor temperature with green roof in the city of Madrid.

The estimation of heat related death is challenging in several parameters of the heat-health relation. A challenge in estimating the premature death attributable to the heat event relays in the estimation of the threshold temperature above which premature death is attributed to the heat event and not to natural death. Some studies have considered the temperature of minimum mortality, the turning point of the U-shape relation between temperature and death (Baccini et al., 2008; Gasparrini et al., 2015; Menne and Ebi, 2006; Watkiss and Hunt, 2011). Others studies refers to the threshold where mortality increases significantly in order to capture heat related death and not only temperature related death (Alberdi et al., 1998; Díaz et al., 2006, 2002; Fouillet et al., 2008). In the city of Madrid, the Heat health Warning System set the alert temperature at 36.5ºC based on epidemiological studies (Alberdi et al., 1998; Díaz et al., 2006, 2002).

From this threshold temperature will depend the calculation of the risk attributable to heat. In Madrid, the attributable risk has been estimated at 21.38%. This means that the daily premature death (all

natural causes) increases by 21.38% when temperature increases by 1ºC above the threshold of 36.5ºC (Linares et al., 2014).

Under UHI reduction obtained from green roofs, the expected avoided mortality is the difference between the mortality due to heat with green roof and UHI reduction with the mortality due under no-UHI reduction. So, it also decomposes into a day effect and a temperature effect. The day effect occurs as the temperature reduction generated by green roofs reduces the number of days where the alert threshold temperature is exceeded. The temperature effect occurs as a lower temperature induces directly lower death from the attributable risk.

The value of statistical life (also value per statistical life) represents the individual willingness to pay for a small risk change, similar over the population in a finite time period divided the risk change or change in survival probability. It has a long history and grew with the needs to evaluate of public policies (Banzhaf, 2014). It is thus the monetary value of a mortality risk reduction that would prevent one statistical death and not one identified life[7] (Hammitt, 2000; Hammitt and Treich, 2007). It measures in other words how much people are willing to pay to substitute wealth (money) for small risk reduction[8]. Whereas the VSL considers premature death (Banzhaf, 2014), the Value of a Life Year (VOLY)[9] considers the change in life expectancy, i.e. a shift in the timing of death[10]. Desaigues et al. (2011) provides from a contingent valuation survey estimates of VOLY at EU scale. They found a VOLY of around 40.000€ for 3 month life expectancy gain. Chilton at al. 2004 estimates a VOLY of (£2004) 7280 £ for 1 month of year life lost.

We followed OCED recommendations to transfer monetary valuation of VSL and VOLY in euro, adjusted by consumer price index and income elasticity of 0.8. OECD recommends in the absence of specific studies the use of a VSL for EU27 of 3.6 million dollars (2005USD) with range of 1.8 and 5.4 million dollars. We transfer this value to Spain. We apply the VSL to premature death and the VOLY estimated by Chilton at al. (2004) to the displaced mortality (those people that would have died whatever the climatic event in a short period of time). We estimated the displaced mortality rate around 40% (Davis et al., 2003; Hajat et al., 2005; Saha et al., 2013).

[7] The controversy relative to the use of VSL in public policies evaluation for non-economists is thus rather a matter of inappropriate use of terminology (Banzhaf, 2014; Cameron, 2010). Value of preventing fatality is also used in the literature (Desaigues et al., 2011)

[8] For example, if an individual is willing to pay four euros to reduce his chance of dying this year by two in a million, his VSL is four divided by two in a million, or two million euros. So if each person in this population pays four euros to reduce the chance of dying this year by two in a million, two million euros would be paid and two life would be expected to be saved and the two beneficiaries would be unidentifiable.

[9] or Value per statistical life-year

[10] The main difference between VOLY and VSL approaches is that in a VSL approach each life saved is valued equally and in a VOLY approach it is valued in proportion to the life expectancy gain. However VOLY and VSL are linked as the VSL is the sum of the discounted flow of annual life year values.

Table 14: Total discounted benefits of CO2 emission reduction services from green roofs, for 2020-2100

	Green roof coverage	Discount rates 0%	1%	2%	3%	5%
Climate change scenarios: SSP2 and Rcp45	**5%**	686 (134.4-1575.3)	453.7 (89.9.-1041.2)	315.3 (62-720.4)	230.1 (43.9-521.1)	139.9 (23.9-308.4)
	20%	2753.3 (412.3-6442.9)	1825.9 (272-4270.1)	1274.8 (188.6-2973.3)	934.2 (137.2-2168.6)	569 (82.9-1302)
	50%	6503.9 (1091.4-15556)	4284.6 (719.4-10191)	2961.1 (498.8-7005.9)	2141.5 (362.8-5041.9)	1262.6 (217.9-2948.2)
	100%	12335.7 (2148-28571)	8052.4 (1423.6-18680)	5518.4 (991.3-12819)	3961.7 (723-9212.5)	2311.2 (434.1-5381.8)
SSP5 and Rcp85	**5%**	1157.1 (247.4-3068.4)	695 (153-1821.6)	433.7 (97.3-1125.3)	281.4 (63.9-725.5)	133.6 (29.7-344.9)
	20%	4170.1 (691.5-10030)	2491.7 (416-5987)	1551.3 (260.5-3742)	1009 (169.9-2457.4)	489.2 (81.9-1229.9)
	50%	9954.9 (1723.6-24794)	5961 (1033.1-15000)	3735.3 (645.2-9505.2)	2456.3 (421-6322.7)	1229 (205.2-3233.4)
	100%	19621 (3343.9-47413)	11863 (1996-28616)	7512.4 (1247-18081)	4993.4 (819-11988)	2549 (410-6088.4)

Low and high values in parentheses. Unit: million euro

The value of avoided mortality is larger in the low mitigation scenario (scenario SSP5/Rcp8.5) than in higher mitigation scenario (SSP2/Rcp4.5). Although this effect is diluted with the discount rate effect: future avoided mortality are less valued as the discount rate increases.

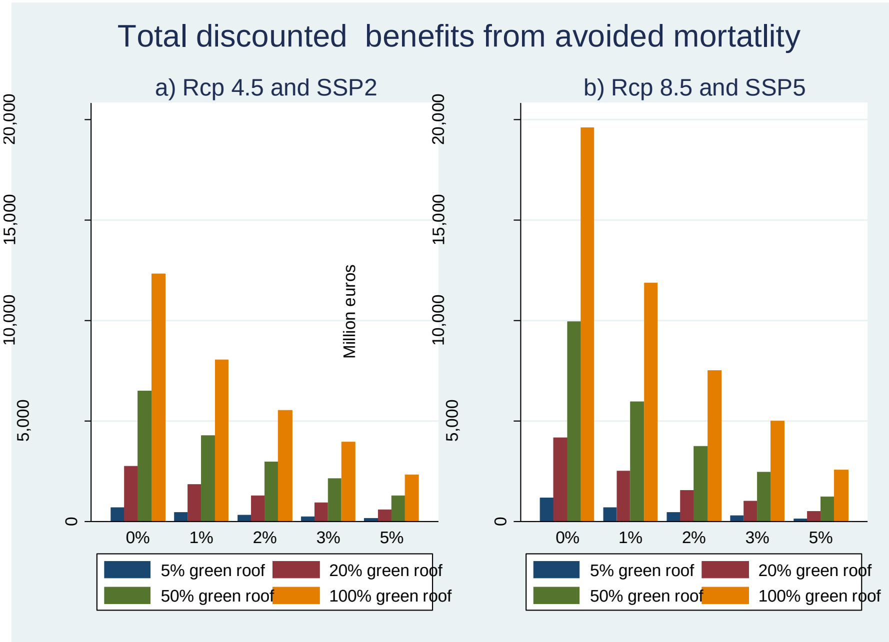
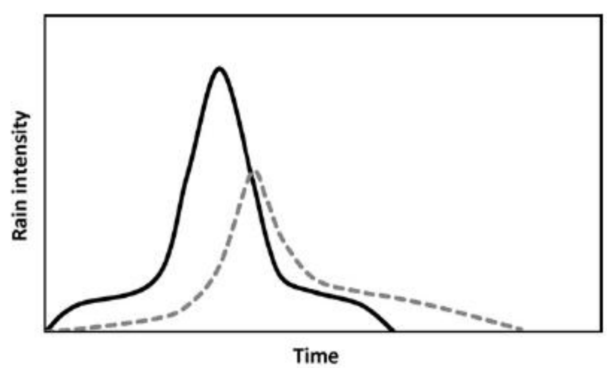


Figure 15: Total discounted avoided mortality from green roof

3. Benefits of green roof: water retention

Green roofs influence the runoffs from rainfall: they delay the time where runoff will occur, reduce the total runoff, enlarge the temporal distribution of runoff as they give slower release of water (Berndtsson, 2010; Mentens et al., 2006). **We will model the volume reduction services.**



Source: (Berndtsson, 2010)

The rate of runoff is influenced by the roof type (slope of the roof, the depth of the substrate, the type of plant community) and the rainfall characteristics: distribution, intensity, duration (Berndtsson, 2010; Oberndorfer et al., 2007). The rainfall-runoff relation is also dependent on local climate characteristics. The quadratic estimation function of Mentens et al. (2006) for green roof is adapted to Western and Occidental European climate: this functional form is not relevant for drier climate. Simulation of this

function for dry climate shows that runoffs from green roof would be higher than from non-green roof which contrary to expectations.

We review the performance of extensive green roofs on water management (Bengtsson et al., 2005; Bliss et al., 2008; Carter and Rasmussen, 2006; DeNardo et al., 2005; Fioretti et al., 2010; Getter et al., 2007; Hutchinson et al., 2003; Liptan, 2003; Liu and Minor, 2005; Mentens et al., 2006; Monterusso et al., 2005; Moran et al., 2005; Nardini et al., 2012; Razzaghmanesh and Beecham, 2014; VanWoert et al., 2005). Most of the papers of the literature refer to humid and continental climates. Regions of the world were runoff retention is challenging a priori due to the high precipitation. Very few refers to Mediterranean climate, only Razzaghmanesh and Beecham (2014).

Table 15: Literature review of water retention coefficient of green roofs

Authors	year	Country	City	Region	Köppen climate classification	Annual rainfall (mm, wikipedia)	Annual retention, %		
							Low	Average	High
Mentens et al	2006	Belgium		Brussels	Oceanic climate	850		54	
Carter and Rasmussen	2006	US	Athens	Georgia	Humid subtropical	1180	39	78	100
Carter et al	2008	US		Georgia	Humid subtropical	1180		77	
Monterusso et al.	2004	US		Michigan	Humid continental	750-1000		49	
Getter et al	2007	US		Michigan	Humid continental	750-1000	75.3	80.2	85.2
VanWoert et al	2005	US		Michigan	Humid continental	750-1000	50	61	98
Moran et al.	2005	US		North Carolina	Humid subtropical	2000	55	59	63
Hutchinson et al.	2003	US		Oregon	Humid subtropical	1000		69	
Liptan	2003	US	Portland	Oregon	Humid subtropical	1000	59	69	92
De Nardo et al.	2005	US		Pennsylvania	Moderate continental	1000	19	45	98
Bliss et al	2009	US		Pennsylvania	Moderate continental	1000	5		70
Bengtsson et al.	2005	Sweden	Malmö	South	Temperate humid	600		46	

					climate				
Liu	2005	Canada	Toronto	Ontario	Humid continental	830		57	
Nardini et al	2008	Italy	Trieste	Friuli–Venezia Giulia	Humid subtropical	1000	63.3	81.9	90.5
Fioretti et al (**)	2010	Italy	Genova	Liguria	Humid subtropical	1000	15	98	100
Razzaghmanesh and Beecham	2014	Australia	Adelaide	South	Mediterranean	550	66	74	81
Beecham and Razzaghmanesh	2015	Australia	Adelaide	South	Mediterranean	550	52	73*	95

*-calculated

**: although Fioretti's title refers to Mediterranean climate, we consider Genova as Humid subtropical.

We use the values of retention of a **Mediterranean climate, similar to the climate of Madrid**. For traditional roof, we used 8%,10% and 13% for the water retention coefficient (Carpenter and Kaluvakolanu, 2011; Mentens et al., 2006).

Although it has been shown that the water retention capacity decreases the intensity of rainfall (Carpenter and Kaluvakolanu, 2011), we consider a constant water retention capacity since our climate data do not inform on the daily pattern of rainfall.

Given that green roof delay the time where runoff will occur, reduce the total runoff, enlarge the temporal distribution of runoff, we could consider that the water retained by green roof is water that is not going to the sewer system and thus does not need to be treated by the water utility. Given the property right of data on real cost of water treatment, we use the price paid by users for water treatment in Madrid. In 2011, this price is 0.63€/m3 for sanitation and purification services. The benefits of green roof for the water retention service is therefore measured in terms of avoided water treatment cost. Table 16 gives the water retention under the different scenario, estimated in % of total rainfall over all the area of the city. For a 20% green roof coverage it varies from 4.4% to 6.5% per year on average over 2020-2100. There is no distinction between Rcps when the water retention is measured in percentage of rainfall.

Table 16: Percentage of overall rainfall retained by green roofs under climate change scenarios

	RCP 4.5		RCP8.5	
Green roofs coverage	**Average retention percentage of total rainfall over**	**Range: Low-high**	**Average retention percentage of total rainfall over**	**Range: Low-high**

	Madrid area, 2020-2100		Madrid area, 2020-2100	
5%	1.39%	1.11% - 1.63%	1.39%	1.11% - 1.63%
20%	5.57%	4.44% - 6.52%	5.57%	4.44% - 6.52%
50%	13.92%	11.09% - 16.31%	13.92%	11.09% - 16.31%
100%	27.83%	22.18% - 32.62%	27.83%	22.18% - 32.62%

The difference between Rcp4.5 and Rcp8.5 does not appear when average percentage are computed.

We present the benefits for SSP2 and RCP4.5 and for SSP5 and RCP8.5 (Table 17 and Figure 16). For a given discount rate, the benefits increase with the share of green roof coverage over Madrid. With a 2% discount rate, the benefits vary from 57.5 million euros with a 5% rate of green roof coverage to 1149 million euros for a total coverage in the climate scenario Rcp4.5 and SSP2. We also observe that benefits are higher in the low mitigation scenario (Rcp8.5) given that precipitation projections give higher rainfall for this scenario. Benefits are also higher in the socio-economic scenario SSP5 than in the socio-economic scenario SSP2, given their respective GDP per capita trends.

Table 17: Total discounted benefits in million euros of water retention services, 2020-2100.

Climate change scenarios		Green roof coverage	Discount rates 0%	1%	2%	3%	5%
	SSP2 and Rcp4.5	**5%**	113.5 (90.1-132.5)	78.4 (62.5-91.91)	57.5 (45.8-67.3)	44.2 (35.2-51.8)	29.4 (23.4-34.4)
		20%	452.2 (360.4-529.9)	313.7 (250-367.6)	229.9 (183.2-269.4)	176.8 (140.9-207.2)	117.5 (93.6-137.7)
		50%	1130.5 (900.9-1324.8)	784.3 (625-919.1)	574.9 (457.9-673.4)	442 (352.2-673.4)	293.8 (234.1-344.2)
		100%	2261.1 (1801.8-2649.7)	1568.6 (1250-1838.2)	1149.4 (915.9-1346.9)	884.1 (704.5-1036)	587.5 (468.2-688.5)
	SSP5 and Rcp8.5	**5%**	117 (93.2-137.1)	82.3 (65.6-96.5)	61 (48.6-71.5)	47.4 (37.7-55-5)	31.8 (25.4-37.3)
		20%	467.9 (372.9-548.3)	329.3 (262.4-385.9)	244.1 (194.5-286.1)	189.4 (151-222)	127.3 (101.4-149.2)
		50%	116.8 (932.2-1370.8)	823.2 (656-964.7)	610.3 (486.3-715.2)	473.6 (377.4-555)	318.2 (253.6-372.9)
		100%	2339.5 (1864.3-2741.6)	1646.5 (1312-1929.5)	1220.5 (972.6-1430.3)	947.2 (754.8-1110)	636.4 (507.2-745.8)

Unit: million euros. Low and high values in parentheses

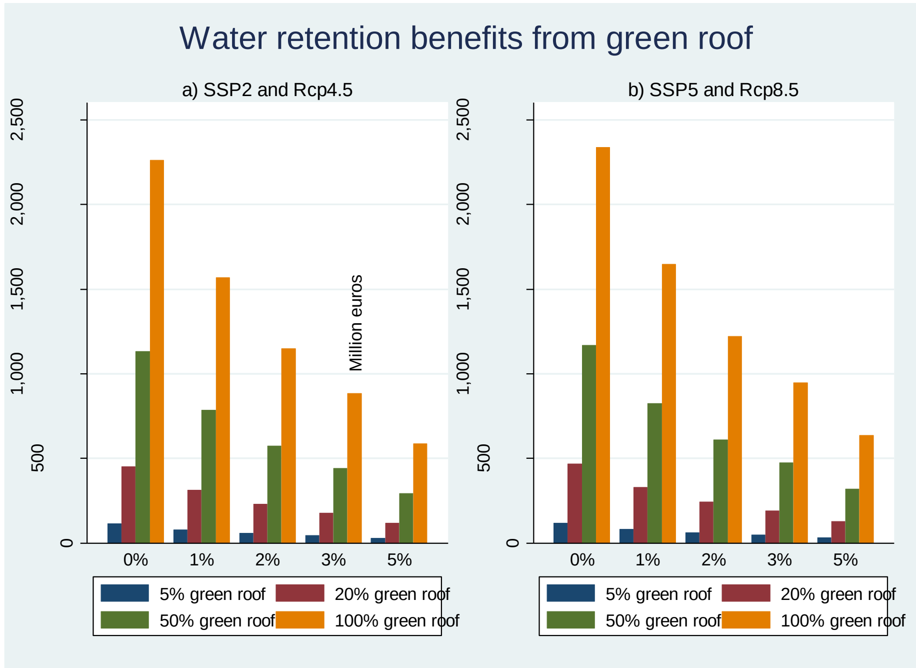


Figure 16: Total discounted benefits of average water retention services for SSP2, 2020-2100

4. Benefits: Avoided maintenance

We consider a 30 years lifespan for the green roof and a renovation of the roof after the age. For traditional roofs we use a 20 years lifespan. Therefore at horizon 2099, the renovation of the traditional roof in 2060 can be avoided if the building is constructed with a green roof. The benefit of green roof is thus estimated as an avoided renovation cost due to lifespan gain.

Table 18: Total discounted benefits of life span gain from green roofs

		Discount rates				
	Green roof coverage	**0%**	**1%**	**2%**	**3%**	**5%**
SSP2	**5%**	308 (247.4-368.6)	206.9 (166.2-247.6)	139.5 (112.1-166.9)	94.4 (75.9-113)	43.8 (35.1-52.4)
	20%	1232.1 (989.7-1474.5)	827.6 (664.8-990.4)	558 (448.2-667.8)	377.7 (303.4-452)	175 (140.6-209.4)
	50%	3080.3 (989.7-3686.3)	2068.9 (664.8-2475.9)	1395 (448.2-1669.5)	944.3 (303.4-1130.1)	437.5 (340.6-523.6)
	100%	6160.6 (4948.7-7372.5)	4137.8 (3323.8-4951.8)	2790.1 (2241.2-3338.9)	1888.6 (1517.1-2260.1)	875.1 (702.9-1047.2)
S P	**5%**	316.7	212.7	143.5	97.1	45

	(254.4-379.1)	(170.9-254.6)	(115.2-171.7)	(78-116.2)	(36.1-53.8)
20%	1267	851	573.8	388.4	180
	(1017.7-1516.2)	(683.6-1018.4)	(460.9-686.7)	(312-464.8)	(144.6-215.4)
50%	3167.5	2127.5	1434.5	971	449.9
	(1017.7-3790.6)	(683.6-2546)	(460.9-1716.7)	(312-1162)	(344.6-538.4)
100%	6335	4254.9	2869	1942	899.9
	(5088.7-7581.2)	(3417.9-5091.9)	(2304.6-3433.4)	(1560-2324.1)	(722.8-1076.9)

Low and high values in parentheses

Unit: million euro

5. Repartition of the five estimated benefits

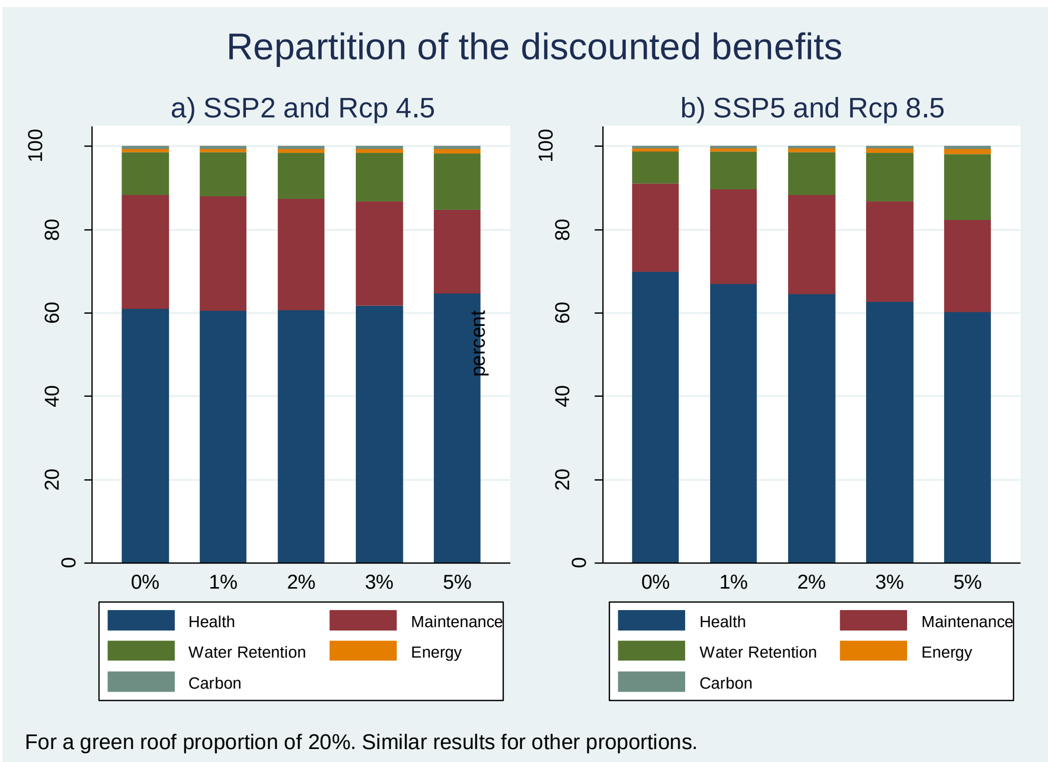


Figure 17 Repartition of the disdounted benefits

Under the specified services valuation assumptions, around 60% of the benefits from green roofs are due to the avoided deaths obtained from the reduction of outdoor temperature, 20% from the reduction in the maintenance costs and about 15% from water retention. Energy savings and carbon footprint reduction are negligible.

B) Heat health warning system in Madrid

In a changing climate heatwaves will pose an increased threat to human health especially in urban areas and among vulnerable groups. To mitigate these impacts, heat health watch warning systems (HHWWS) are usually set up to warn the population, give early alerts, advisories and emergency measures to mitigate the impact of a heat wave. A heat warning alert is usually triggered when climatic variables exceed specified criteria which might include daily maximum temperature, relative humidity, among others which can be used to define a cut-off temperature when excess mortality is expected to increase rapidly. The choice of the cut-off temperature is therefore an essential parameter if a HHWWS is to be operated effectively as a counter-measure (adaptation) to reduce the heat-related health impacts in the context of a changing climate in which the frequency, intensity and duration of heat waves is expected to increase in the coming decades. In the future, local governments in urban areas that currently are not faced with severe heat events will have to consider, outline, fund and execute contingency plans to protect its citizens against the increased risks posed by climate change. Not only is the climate changing, but urban morphology will likely exacerbate the potential severity of the health impacts. Therefore, knowledge of this critical temperature and more importantly how it might vary over space and time due to climatic parameters, socioeconomic conditions, population health status, and people's behavioural responses to a changing environment will have a profound influence on the effectiveness of prevention measures, including the efficacy of a HHWWS.

In the case study for Madrid, we conducted a cost-benefit analysis of the HHWWS to analyse the long-term costs and benefits (2020-2100) of running the system under different climate scenarios and to identify the additional costs of implementation if acclimatisation processes are not properly considered (in terms of changing critical temperature, attributable risk on health and displaced mortality ratio).

In order to estimate the health risks and the critical temperature (Tcrit) defining an episode of heatwave, an epidemiological study was carried out in collaboration with the Instituto Carlos III (Cristina Linares Gil, Rocío Carmona Alférez, Julio Díaz Jiménez, Escuela Nacional de Sanidad, September 2014). In this study we found that in the period 2001-2009 the Tcrit has decreased to 34 °C compared to the period 1986-1997, in which this temperature was established at 36.5°C. Nevertheless, the current HHWWS is set up on the temperature of 36.5°C which implies a loss of health benefits which would be otherwise observed if the system were launched at the new threshold.

We present here below the assumptions behind the baseline and projection scenarios for the time span 2020-2100, and afterwards the results in terms of economic costs, physical and economic benefits, cost-benefit ratios (BCR) and differences in costs and benefits when running the system without taking into account the correct set up of Tcrit over time.

Scenarios

<u>Baseline scenario</u>

The notion of threshold or critical temperature (Tcrit) is crucial in the definition of a HHWWS. This is the temperature above which the daily mortality is expected to start increasing significantly. Health risks

and Tcrit have been estimated for the years 2001-2009 by Diaz et al (2014a) specifically for the case study of Madrid. Figure 14 shows the maximum daily temperature and mortality residuals to define a heatwave episode in Madrid. As it can be seen from the figure, mortality residuals start to increase significantly at the temperature of 34°C, instead of 36.6°C at which the current HHWWS for Madrid is set up.

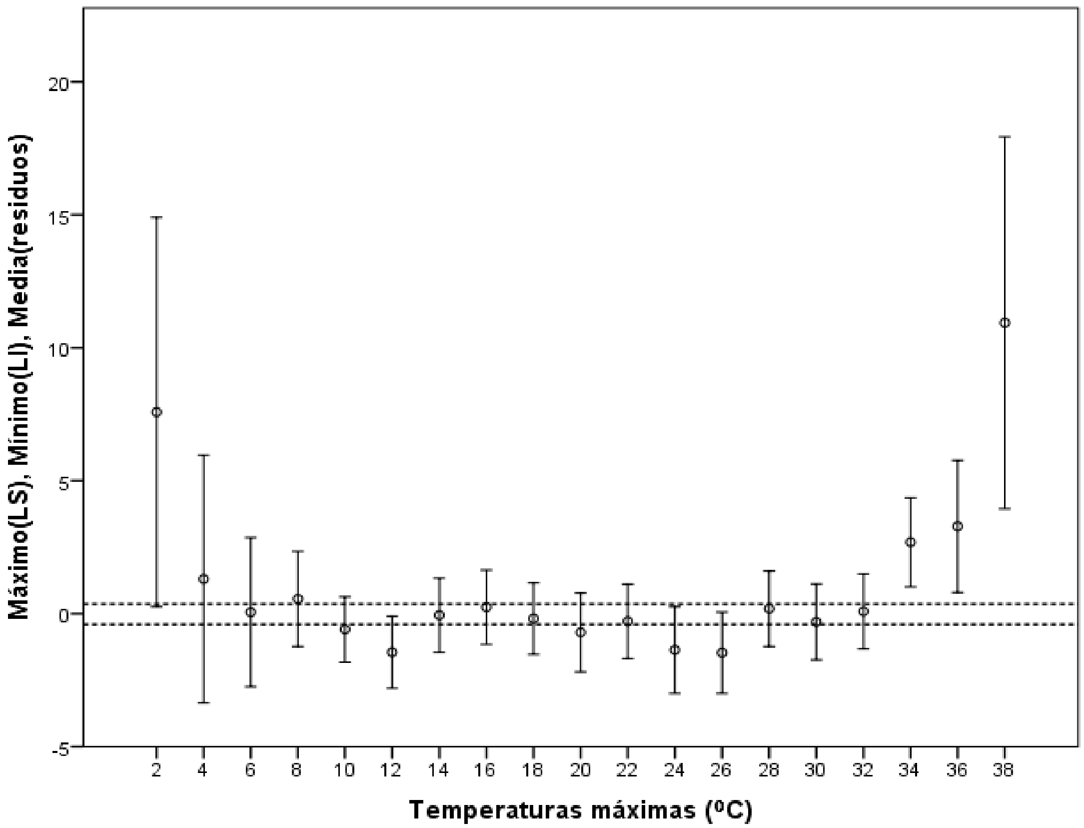


Figure 14. Maximum daily temperature and mortality residuals in Madrid. Source: Diaz et al (2014a)

Diaz et al (2014a) estimated also the health risks (as attributable risks AR) associated with heatwaves (in terms of increased mortality all causes, cardiovascular and respiratory, for all ages and for different age groups). AR is defined as the percentage increase in daily mortality attributable to heatwaves, for each degree centigrade where the maximum temperature is above Tcrit (Diaz et al, 2014a). Table 15 presents RR and AR related to daily mortality attributable to heatwaves. The AR estimated is equal to 4.24% for each degree increase in maximum temperature above the threshold.

Table 15. Variations in relative risk (RR) and attributable risk (AR) related to daily mortality caused by heat waves.

	Variable	RR	IC 95%		RA(%)	IC 95%	
Total causas naturales (CIE-10: A00-R99)							
Todo el año (N= 2149)	$PM_{2.5}$ (lag 2)	1,008	1,000	1,016	0,83	0,04	1,61
	Tcal (lag 2)	1,022	1,008	1,036	2,15	0,79	3,47
	Tfrio (lag 1)	1,039	1,008	1,072	3,77	0,75	6,70
	Tfrio (lag 7)	1,045	1,016	1,075	4,33	1,56	7,01
	NO_2 (lag 1)	1,007	1,003	1,010	0,67	0,31	1,02
	Olea (lag 1)*	1,003	1,000	1,005	0,25	-0,02	0,52
	Tasa Gripe(lag 1)	1,005	1,004	1,006	0,52	0,41	0,63
	Leq24 (lag 0)	1,018	1,014	1,022	1,75	1,37	2,14
Verano (N=732)	$PM_{2.5}$ (lag 0)	1,022	1,005	1,040	2,16	0,47	3,81
	Tcal (lag 1)	1,023	1,008	1,037	2,22	0,84	3,58
	Tcal (lag 3)	1,021	1,007	1,034	2,02	0,73	3,30
	Leq24 (lag 0)	1,018	1,011	1,025	1,77	1,06	2,47
	Leqn (lag 3)	1,006	1,001	1,011	0,61	0,10	1,12
Invierno (N=907)	$PM_{2.5}$ (lag 1)	1,021	1,006	1,009	2,10	0,64	0,87
	Tfrio (lag 1)	1,038	1,010	1,066	3,62	1,00	6,16
	Tfrio (lag 7)	1,044	1,017	1,073	4,25	1,65	6,79
	Tfrio (lag 11)	1,029	1,001	1,057	2,77	0,10	5,37
	Tasa Gripe(lag 0)	1,001	1,001	1,001	0,08	0,06	0,09
	Leqd (lag 0)	1,007	1,003	1,011	0,68	0,31	1,05
	Leq24 (lag 1)	1,010	1,003	1,017	1,00	0,35	1,64
	Leq24 (lag 3)	1,007	1,000	1,013	0,65	0,03	1,26

Source: Diaz et al (2014a)

Diaz et al (2014b) estimated that the majority of deaths would occur for people older than 74. In our case study we distinguish between two mortality effects: premature and displaced mortality. Premature mortality refers to people in normal health who would die because of the heatwave, while displaced mortality concerns people already in poor health (for example because of pre-existing cardio-vascular or respiratory problems) who would die in the short term anyway, regardless of the heatwave. Displaced mortality refers therefore to a shift in mortality rate, and it is also known as harvesting effect. According to our estimates, for people in poor health the heatwave episode would shorten their life expectancy between one week and one month (assuming a lognormal distribution). The mean loss of life, calculated over the period 2020-2100 is about 16 days per death. For premature mortality, the loss of life expectancy has been estimated between 6 months (which increases to 1 year by 2100) and the remaining life expectancy at the age of the death (assuming a lognormal distribution). The mean loss of life over 2020-2100 is about 4.7 years per premature death. Life years loss calculations account for time changes in life expectancy as a function of age group, future changes in demographics (cohort shares), and distribution of heat deaths (both premature and displaced) among cohort classes. Displaced

mortality rate has been set up at 40% and 65% (Hajat et al, 2005), and the rate of 40% has been used for carrying out the CBA.

For our calculations, the baseline scenario is constructed over the period 2004-2009. We chose this time frame as the HHWWS was established in 2003.

Projection scenarios (2020-2100)

Having established the appropriate Tcrit for the baseline, we have constructed the following scenarios to project the costs and benefits of the HHWWS by the end of the century (2100):

RCP4.5, SSP2

- Scenario 1 (S1): no acclimatisation, Tcrit (34°C), attributable risk (AR=4.24%) and displaced mortality ratio (DMR=40%) constant over time.
- Scenario 1a (S1a): with acclimatisation, Tcrit, attributable risk (AR) and displaced mortality ratio (DMR) changing over time.

RCP8.5, SSP5

- Scenario 2 (S2): no acclimatisation, Tcrit (34°C), attributable risk (AR=4.24%) and displaced mortality ratio (DMR=40%) constant over time.
- Scenario 2a (S2a): with acclimatisation, Tcrit, attributable risk (AR) and displaced mortality ratio (DMR) changing over time.

Critical temperature in the baseline scenario is set up at 34°C as estimated in Diaz et al (2014a) for the period 2004-2009. We expect the Tcrit to increase over time due to an effect of: physical acclimatisation (the number of deaths due to heat is higher at the beginning of the summer than at the end), adaptation measures (such as emergency systems, medical assistance or green infrastructures) and behavioural changes (because of improved information).

The projected evolution of Tcrit in the acclimatisation scenarios between 2020 and 2100 is based on a probability density function elaborated on projections of future daily maximum temperatures provided by CMCC. Tcrit has a "hockey-stick" shape with varying threshold values and approximate linear behaviour thereafter. The short and long lag curves coincide with the 95% CI of Tcrit by the end of the century. The line identifies the annual mean Tcrit temperature of the random, stepwise Tcrit trajectories assumed in the Monte Carlo simulations.

A HHWWS is a low regret urban adaptation option to climate change, and consequently, highly relevant for decision-making. The HHWWS usefulness depends on the correct specification of Tcrit. Current long-term studies of heatwave impacts assume constant Tcrit, but decadal variations of Tcrit have been reported in Castilla-La Mancha, Spain (BASE). Failure to recognize time-dependence of Tcrit is likely to render HWWS, and other urban adaptation measures, inefficient, and potentially cost-ineffective.

Figures 15 and 16 show the evolution of Tcrit (medium lag) for RCP4.5 and 8.5.

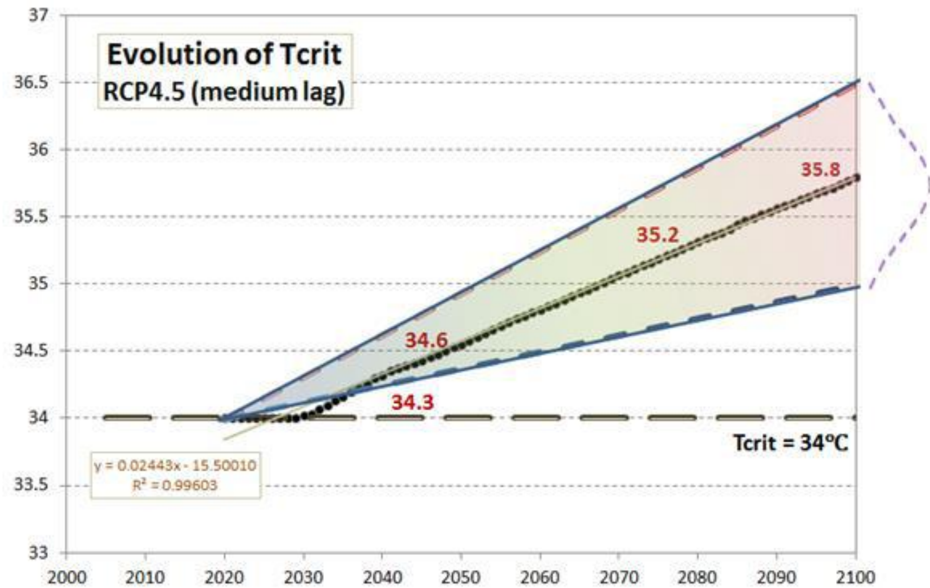


Figure 15: projected evolution of Tcrit (℃) between 2020 and 210 for scenario RCP4.5

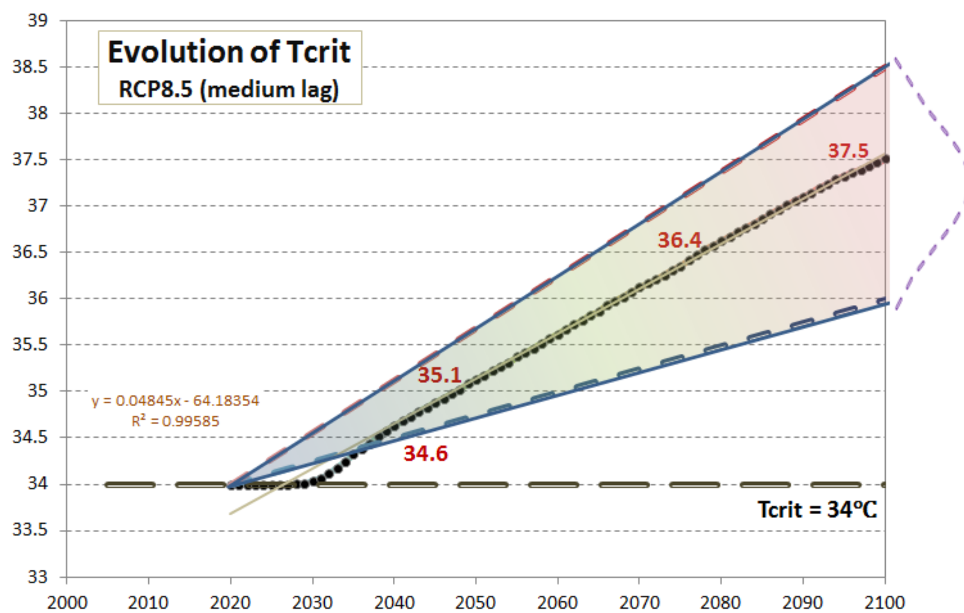


Figure 16: projected evolution of Tcrit (℃) between 2020 and 210 for scenario RCP8.5

The potential scenarios of *attributable risk* evolution for Madrid over the period 2020-2100 are shown in figure 17, considering a scenario of acclimatization where Tcrit is changing over time. AR can be estimated as a function of Tcrit over time: RA=0.016342 T_{crit}−0.51322 (mean curve)

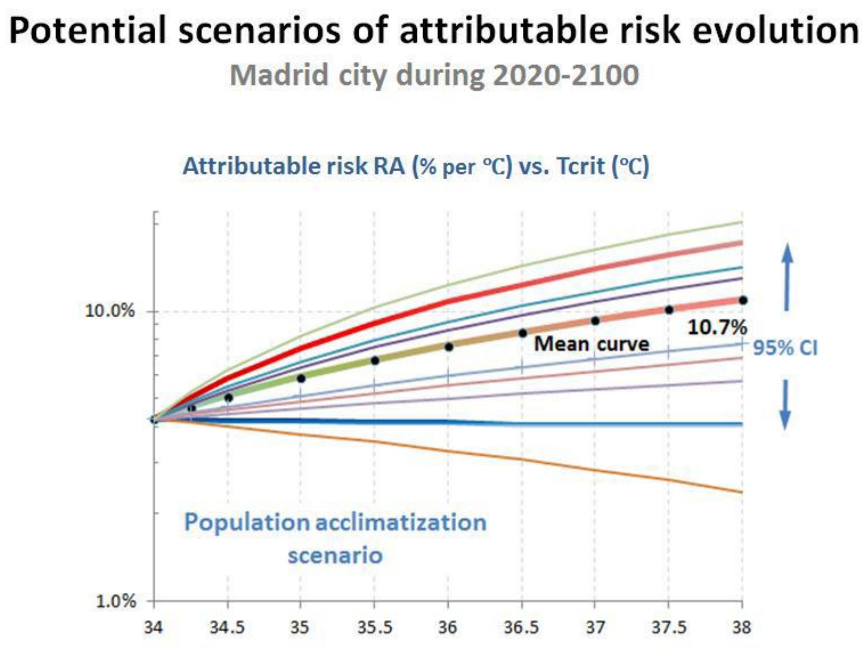


Figure 17: Evolution of attributable risk with changing Tcrit.

Finally, as regards the *displaced mortality rate* (DMR), this is assumed to decrease over time when Tcrit is increasing. Figures 18 and 19 show the projected evolution of DMR as a function of Tcrit over the period 2020-2100.

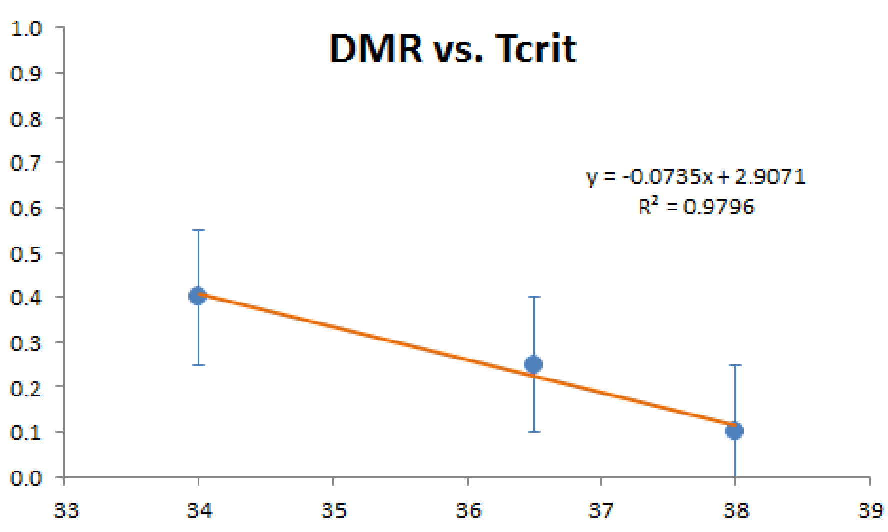


Figure 18: Evolution of DMR as a function of Tcrit (40% in 2020).

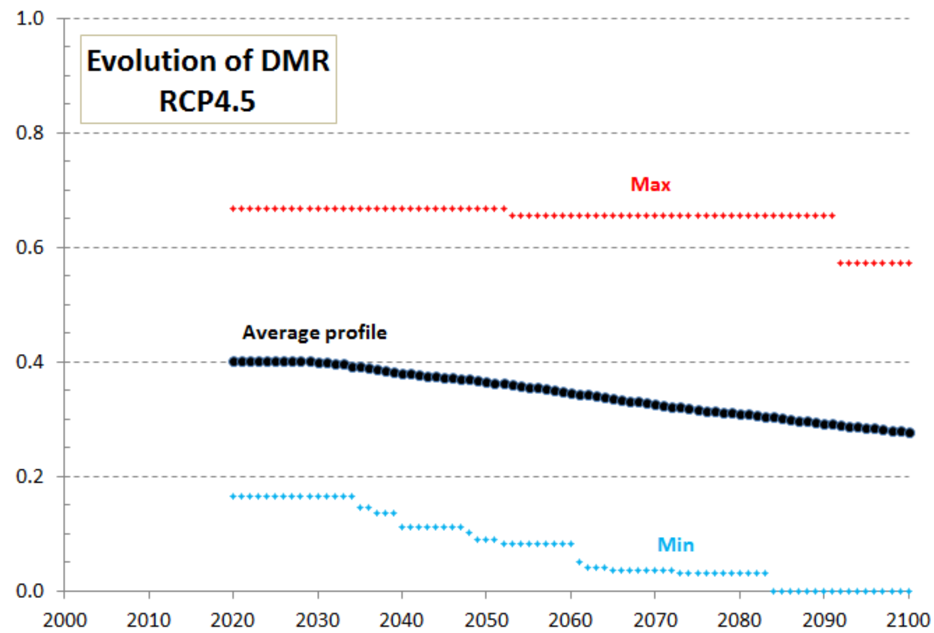


Figure 19: Projected evolution of DMR in the period 2020-2100.

In the next sections we present the estimation of the costs and benefits related to the HHWWS under the baseline and projection scenarios, together with the BCR.

- **Costs**

Total annual costs of the HHWWS are related to the number of days of alert (the days in which the maximum temperature is expected to be above Tcrit), which depends on the Tcrit and differs in the climate scenarios RCP 4.5 and 8.5.

Total annual cost = Cost per day of alert * Number of days of alert (L)

The unit costs used for the HHWWS of Madrid are based on two references, Ebi et al. (2004) for the variable costs and personal interviews to stakeholders in Madrid for the fixed cost of the heatline.

Cost of heatline:

- Fixed costs of maintenance of the system: 500€ per year (2013€/yr) (personal communication with Health Department of Madrid Salud),
- Variable costs due to personal (average): 3,375€/day (2013€/day) (750-6,000€/day, adapted from Ebi et al, 2004).

Total implementation costs of the system depend on the number of days in which the HHWWS is activated, which is the number of days in which the maximum temperature exceeds the critical stated

threshold. For Madrid, the epidemiological study of Diaz et al (2014a) found that in the period 2001-2009 the Tcrit has decreased to 34 °C compared to the period 1986-1997, in which this temperature was established at 36.5°C. Nevertheless, the current HHWWS is set up on the temperature of 36.5°C which implies a loss of health benefits which would be otherwise observed if the system were launched at the new threshold.
We present here below the total costs of HHWWS projected costs 2100, as well as the additional costs that would be supported if the Tcrit is not correctly set up taking into account the acclimatisation process.

Projections of costs to 2100

Tables 16 and 17 show the discounted costs of implementation of the HHWWS in the two scenarios: with acclimatization and without acclimatization, for three estimates of the unit cost (low, medium and high).

Table 16. Total discounted costs of HHWWS in Madrid, period 2020-2100, RCP4.5, SSP2 (M€2013).

S1 - no acclimatisation, Tcrit constant=34	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=low	2.01	1.35	0.95	0.71	0.44
HHWScost=avg	8.90	5.96	4.21	3.13	1.96
HHWScost=high	15.80	10.58	7.48	5.56	3.48
S1a - acclimatisation, Tcrit increasing	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=low	1.62	1.12	0.82	0.62	0.41
HHWScost=avg	7.13	4.94	3.61	2.76	1.80
HHWScost=high	12.65	8.76	6.40	4.89	3.20

Table 17. Total discounted costs of HHWWS, period 2020-2100, RCP8.5, SSP5 (M€2013).

S2 - no acclimatisation, Tcrit constant=34	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=low	2.70	1.74	1.18	0.85	0.51
HHWScost=avg	12.00	7.71	5.25	3.77	2.25
HHWScost=high	21.30	13.69	9.31	6.69	4.00
S2a - acclimatisation, Tcrit increasing	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=low	1.70	1.15	0.82	0.62	0.40
HHWScost=avg	7.50	5.06	3.62	2.74	1.79
HHWScost=high	13.30	8.97	6.42	4.86	3.17

If the evolution of Tcrit is not taken into account when running the HHWWS, the society would incur in additional costs of implementation of the system when it is not necessary (because there is no additional expected mortality due to heatwaves). Table 18 shows the additional costs of running the HHWWS at the wrong temperature for RCP4.5 and 8.5 (assuming the discount rate equal to 0), and not taking into account a variation of AR and DMR. The economic loss would range from 25% to 60% increase in the costs of implementation. The costs are higher in RCP8.5 due to the higher number of

days of alert as well as to the increased costs under SSP5. For the exemplification, we consider average values for the HHWS effectiveness.

Table 18. Additional costs for running the HHWWS with incorrect Tcrit, period 2020-2100 (M€2013), d=0 (average costs).

	Ndays	Cost HHWS (avg, M€2013)
RCP4.5		
S1	2,456	8.90
S1a	1,957	7.13
Additional costs	25%	25%
RCP8.5		
S2	3,243	12.00
S2a	2,011	7.50
Additional costs	61%	60%

- **Benefits**

Estimation of health impacts

The benefits associated with the HHWWS are the avoided deaths or the increased life expectancy in term of life years. The expected mortality due to heat wave is calculated as follows:

$$EM_{\bar{t}} = RA_{\bar{t}} \times \mu \times \Delta T_{\bar{t}} \times L_{\bar{t}}$$

Where $EM_{\bar{t}}$ the expected mortality for the Tcrit $\bar{t}$, $RA_{\bar{t}}$ is the attributable risk for Tcrit $\bar{t}$, μ is the average daily mortality for all causes for the whole population calculated during the heatwaves, $\Delta T_{\bar{t}}$ is the excess temperature above the Tcrit $\bar{t}$ and $L_{\bar{t}}$ is the number of days above Tcrit $\bar{t}$. The expected premature mortality is calculated by subtracting the displaced mortality rate:

$$PEM_{\bar{t}} = RA_{\bar{t}} \times \mu \times \Delta T_{\bar{t}} \times L_{\bar{t}} \times (1 - DMR)$$

Similarly, for estimating the total years of life lost (LYL):

$$PLYL_{\bar{t}} = RA_{\bar{t}} \times \mu \times \Delta T_{\bar{t}} \times L_{\bar{t}} \times PLLE_{\bar{t}}$$

$$DLYL_{\bar{t}} = RA_{\bar{t}} \times \mu \times \Delta T_{\bar{t}} \times L_{\bar{t}} \times DLLE_{\bar{t}}$$

Where *PLLE* is the loss of life expectancy per death for premature mortality and *DLLE* is the loss of life expectancy per death for displaced mortality.

$$TOTLYL_{\bar{t}} = PLYL_{\bar{t}} + DLYL_{\bar{t}}$$

In order to compute the total deaths (*AM*) which could be avoided through the HHWS, we multiply the above expected mortality (or *LYL*) by the effectiveness (*E*) of the HHWWS as estimated by Fouillet et al, 2008 (avg=68%, low=60%, high=76%).

$$AM_{\bar{t}} = EM_{\bar{t}} \times E$$

Table 19 presents the health impacts (in terms of total deaths as well as LYL, both for premature and displaced mortality) for RCP4.5 and 8.5 with and without acclimatisation. The scenarios of acclimatisation (S1a and S2a) include a variation not only of Tcrit, but also of AR and DMR over time.

Table 19. Health impacts under different climate scenarios (DMR 40% and decreasing over time).

Scenario	Tot deaths	Premature deaths	Tot LYL	Premature LYL	Displaced LYL
RCP4.5					
S1	20,410	12,246	57,915	57,557	358
S1a	18,447	12,107	57,179	56,901	278
	(-9.6%)	(-1.1%)	(-1.3%)	(-1.1%)	(-22.3%)
RCP8.5					
S2	33,168	19,901	94,115	93,533	582
S2a	26,756	20,561	96,908	96,636	272
	(-19.3%)	(+3.3%)	(+3%)	(+3.3%)	(-53.3%)

In a scenario of acclimatisation (as defined by a variation of Tcrit, AR and DMR) total deaths are reduced by 9.6% (RCP4.5) and 19.3% (RCP8.5). Over time, however, AR increases while DMR decreases, both effects contributing to an increase in the number of projected premature deaths under the acclimatisation scenario in RCP8.5.

In RCP4.5 the health benefits are lower in a scenario of acclimatisation using any of the proposed health indicators. As expected, this is due to a decrease in the number of days in which maximum daily temperature is higher than Tcrit, which indicates a decrease in people vulnerability. Though with acclimatisation there is an increase of AR and a decrease in DMR on average, these effect are lower than the decrease in Ndays. In RCP8.5, however, the effects of AR and DMR variation over time are much larger than the decrease in Ndays, which entails an increase in the number of premature deaths and LYL over time.

For the CBA, we evaluate the health benefits using premature and displaced LYL and VOLY estimates, in order to provide a lower bound of the economic benefits. Using the number of deaths and VSL would increase considerably the economic benefits.

Monetisation of the health impacts

For the monetisation of the health impacts, two measures can be used: the Value of Statistical Life (VSL) or the Value of a Life Year (VOLY). For the case study, we decided to use the following values and scenarios for the health economic valuation:

- VSL for all deaths (OECD, 2011).
- VSL only for premature deaths (OECD, 2011).
- VSL (OECD, 2011) only for premature deaths and no value for displaced mortality (following OECD guidelines, and considering that there is some evidence in the literature that respondents give no value to a gain in life expectancy in poor health (Chilton et al, 2004, found that more than half of the respondents interviewed stated zero WTP for small changes in life expectancy is in poor health).
- VOLY for premature mortality (de Ayala and Spadaro, 2014) and VOLY (Chilton et al 2004) for displaced mortality.

The values for VSL suggested by OECD (2011) range from 1.8 to 5.4 million US$2005 for all Europe. The values for VOLY proposed by Chilton et al (2004) for DEFRA refer to both normal and poor health, and for 1, 3 and 6 months gain in life expectancy in a context of air pollution. Their values are reported in table 20 below. We use these values for one month gain in poor health as the estimated gain in life expectancy for Madrid ranges from one week to one month, so that we think that the values proposed by Chilton for acute mortality are the most appropriate if we want to monetize this small benefit.

Table 20. VOLY (£2004) – Chilton et al. (2004)

	Normal health	**Poor health**
1 month sample	27,630	7,280
3 months sample	9,430	1,600
6 months sample	6,040	1,290

Finally, for premature mortality we use the VOLY estimated by de Ayala and Spadaro (2004) adjusted for VSL/VOLY chronic impacts. Original values have been adjusted following OECD guidelines (2011) taking into account:

- conversion to national currencies (PPP-adjusted exchange rates)
- domestic Consumer Price Index (CPI) for adjust to the current prices in individual countries
- income adjustment in individual countries (in terms of GDP per capita) from the study site to the policy site (using 0.8
- correction of increased real income in time

Tables 21-22-23 show original and adjusted values in Euro2013 (under different assumptions of income elasticity over space and time). For the CBR in our case study, we use an elasticity of 0.8 for adjustment over space, and 1 for adjustment over time. For sensitivity analysis, the values reported in the tables below can be used, though the differences are quite small.

Table 21. VSL for EU-27 (US$2005) (OECD, 2011) adjustment.

VSL original (OECD report 2011) million US$2005	VSL adjusted million Euro2013		
income elasticity over space	0.4	0.8	1
income elasticity over time	1	1	1
1.80	1.52	1.47	0.92
3.60	3.04	2.94	1.84
5.40	4.57	4.41	2.76

Table 22. VOLY for EU-27 (Euro2013) (de Ayala and Spadaro, 2014) adjustment.

VOLY original (Spadaro 2004) (euro2013) 90,000	VOLY adjusted (Euro2013)
income elasticity over space	
0.4	83,946
0.8	78,299
1.0	75,620

Table 23. VOLY for UK (£2004) (Chilton et al, 2004) adjustment.

VOLY original (Chilton et al 2004) (£2004) 7,280	VOLY adjusted (Euro2013) income elasticity over time		
income elasticity over space	0.4	0.8	1
0.4	9,002	8,815	8,722
0.8	7,641	7,482	7,404
1.0	7,040	6,893	6,821

The final values used are summarised in the table below (table 24).

Table 24. Economic values used for the monetization of the health benefits.

Monetary value	Health indicator	Source
VSL = 2.94 Million Euro2013	All deaths, and premature deaths	OECD, 2011
VOLY = 7,404 Euro2013	Displaced years life lost	Chilton et al, 2004
VOLY = 78,299 Euro2013	Premature years life lost	Spadaro and de Ayala, 2014

<u>Projections of benefits to 2100</u>

Tables 25 and 26 show the discounted economic benefits of the HHWWS in the four scenarios for RCP4.5 and 8.5 over the period 2020-2100. We carried out the analysis for all the scenarios of economic valuation, but we show the results only in one case: VOLY for premature mortality (de Ayala and Spadaro, 2014) and VOLY (Chilton et al 2004) for displaced mortality, as this represents the lower bound

estimate for the monetary benefits. In all other cases, the CBR would be higher as the monetary benefits are higher.

Table 25. Discounted economic benefits of the HHWWS, scenario RCP4.5 (SSP2), VOLY estimates for premature mortality (based on de Ayala and Spadaro, 2014) and displaced mortality (based on Chilton et al, 2004).

S1 - no acclimatisation, Tcrit constant=34	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWSeff=low	3,170	2,057	1,403	1,003	583
HHWSeff=avg	3,602	2,337	1,594	1,140	662
HHWSeff=high	4,082	2,649	1,806	1,292	750
S1a - acclimatisation, Tcrit increasing	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWSeff=low	3,134	2,038	1,393	998	580
HHWSeff=avg	3,561	2,316	1,583	1,134	659
HHWSeff=high	4,036	2,625	1,794	1,285	747

Table 26. Discounted economic benefits of the HHWWS, scenario RCP8.5 (SSP5), VOLY estimates for premature mortality (based on de Ayala and Spadaro, 2014) and displaced mortality (based on Chilton et al, 2004).

S2 - no acclimatisation, Tcrit constant=34	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWSeff=low	5,251	3,170	2,011	1,344	698
HHWSeff=avg	5,968	3,603	2,285	1,527	794
HHWSeff=high	6,763	4,083	2,590	1,730	899
S2a - acclimatisation, Tcrit increasing	**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWSeff=low	5,420	3,221	2,015	1,331	682
HHWSeff=avg	6,159	3,660	2,290	1,512	776
HHWSeff=high	6,980	4,148	2,595	1,714	879

What is the evaluation time frame?

What is the lifespan of the measure with the longest lifetime?

The evaluation time frame is 80 years, 2020-2100. We consider that green roof has an initial cost and a maintenance cost. The maintenance cost account for a renewing of the roof every 30 years in addition to the annual maintenance.

For the HHWWS, the time frame considered is also 80 years from 2010 to 2100. The costs of the HHWS are fixed costs of maintaining the system and variable costs per days. The latter are multiplied by the number of days in which the system is expected to be launched (when the maximum daily temperature is higher than the stated critical threshold Tcrit).

What is the evaluation time frame?

What is the lifespan of the measure with the longest lifetime?

The evaluation time frame is 80 years, 2020-2100. We consider that green roof has an initial cost and a maintenance cost. The maintenance cost account for a renewing of the roof every 30 years in addition to the annual maintenance.

The costs of the HHWS are fixed costs of maintaining the system and variable costs per days. The latter are multiplied by the number of days in which the system is expected to be launched (when the maximum daily temperature is higher than the stated critical threshold Tcrit).

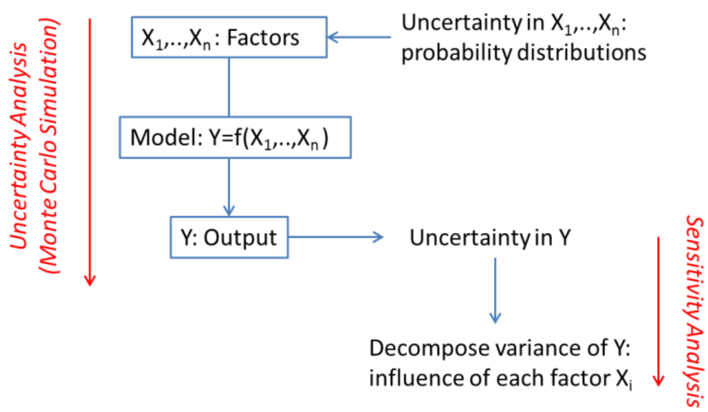
Which discount rate should be applied?

Which discount rate is recommended by national guidelines for climate change adaptation measures (or public investments)?

We use a linear discounting over time. We give results for a 0%, 1%, 2%, 3% and 5% discount rate.

How to deal with data uncertainty?

- Can uncertainties related to the performance of the measures regarding certain evaluation criteria be described by a range (min-max), a triangular distribution (min, most likely, max) or any other kind of probability distribution?
  Uncertainties are considered in the case study both in the scaling parameter setting and in the analysis of the results. In the first place a Monte Carlo simulation is performed on socioeconomic and climatic data. The cost-benefit analysis includes a sensitivity analysis. Image xx shows the methodology used to analyse uncertainty in the case study.



Step 5 – Evaluation and Priorization (max 1500 words)

What is the ranking order of alternative adaptation options (measures, bundles of measures or pathways)?

What is the benefit-cost ratio?

- **Benefit-Cost ratio for green roof in Madrid**

Table 19 and Table 20 shows the benefits-costs ratio under the socio-climatic scenario: SSP2/Rcp4.5 and SSP5/Rcp8.5.

Table 19: The benefit cost ratio for SSP2 and Rcp4.5

		Low/Low	Low/ Medium	Low/High	Medium/Low	Medium/Me dium	Medium/Hig h	High/Low	High/Mediu m	High/High
Discount arte		**Green roof 5%**								
	0%	0.67	0.27	0.15	**1.68**	0.67	0.38	**3.52**	**1.41**	0.80
	1%	0.58	0.22	0.12	**1.40**	0.53	0.30	**2.88**	**1.09**	0.62
	2%	0.48	0.17	0.10	**1.13**	0.41	0.23	**2.29**	0.82	0.47
	3%	0.38	0.13	0.08	0.90	0.31	0.18	**1.79**	0.62	0.35
	5%	0.23	0.08	0.04	0.57	0.19	0.11	**1.11**	0.37	0.21
Discount rate		**Green roof 20%**								
	0%	0.60	0.24	0.14	**1.61**	0.64	0.36	**3.20**	**1.28**	0.73
	1%	0.52	0.20	0.11	**1.34**	0.51	0.29	**2.65**	**1.00**	0.57
	2%	0.43	0.15	0.09	**1.09**	0.39	0.22	**2.13**	0.77	0.44
	3%	0.34	0.12	0.07	0.87	0.30	0.17	**1.69**	0.59	0.34
	5%	0.22	0.07	0.04	0.55	0.18	0.11	**1.09**	0.36	0.21
Discount rate		**Green roof 50%**								
	0%	0.60	0.24	0.14	**1.56**	0.62	0.35	**3.15**	**1.26**	0.71
	1%	0.52	0.20	0.11	**1.30**	0.49	0.28	**2.61**	0.99	0.56
	2%	0.43	0.16	0.09	**1.05**	0.38	0.22	**2.10**	0.76	0.43
	3%	0.35	0.12	0.07	0.84	0.29	0.17	**1.67**	0.58	0.33
	5%	0.22	0.07	0.04	0.53	0.18	0.10	**1.07**	0.35	0.20
Discount rate		**Green roof 100%**								
	0%	0.60	0.24	0.14	**1.53**	0.61	0.35	**3.01**	**1.20**	0.68
	1%	0.52	0.20	0.11	**1.28**	0.48	0.27	**2.48**	0.94	0.53
	2%	0.43	0.15	0.09	**1.04**	0.37	0.21	**2.00**	0.72	0.41
	3%	0.35	0.12	0.07	0.83	0.29	0.16	**1.58**	0.55	0.31
	5%	0.22	0.07	0.04	0.52	0.17	0.10	**1.01**	0.34	0.19

Low/Low means the benefit-cost ratio has been estimated with the low estimates of the benefits and the low estimates of the cost. Low/Medium means low benefits and low costs. A ratio < 1 means that the costs are higher than the benefits and would led to the no-implementation of the policy.

Table 20: The benefit cost ratio for SSP5 and Rcp8.5

		Low/Low	Low/ Medium	Low/High	Medium/Low	Medium/Me dium	Medium/Hig h	High/Low	High/Mediu m	High/High
Discount arte		**Green roof 5%**								
	0%	0.67	0.27	0.15	**1.68**	0.67	0.38	**3.53**	**1.42**	0.80
	1%	0.58	0.22	0.12	**1.41**	0.53	0.30	**2.89**	**1.09**	0.62
	2%	0.48	0.17	0.10	**1.14**	0.41	0.23	**2.30**	0.83	0.47
	3%	0.38	0.13	0.08	0.90	0.31	0.18	**1.80**	0.63	0.36
	5%	0.24	0.08	0.04	0.57	0.19	0.11	**1.12**	0.37	0.21
Discount rate		**Green roof 20%**								
	0%	0.60	0.24	0.14	**1.61**	0.65	0.37	**3.22**	**1.29**	0.73
	1%	0.52	0.20	0.11	**1.35**	0.51	0.29	**2.66**	**1.01**	0.57
	2%	0.43	0.16	0.09	**1.10**	0.40	0.22	**2.14**	0.77	0.44
	3%	0.35	0.12	0.07	0.87	0.30	0.17	**1.70**	0.59	0.34
	5%	0.22	0.07	0.04	0.56	0.19	0.11	**1.09**	0.36	0.21
Discount rate		**Green roof 50%**								
	0%	0.61	0.24	0.14	**1.56**	0.63	0.35	**3.16**	**1.27**	0.72
	1%	0.52	0.20	0.11	**1.31**	0.49	0.28	**2.62**	0.99	0.56
	2%	0.43	0.16	0.09	**1.06**	0.38	0.22	**2.11**	0.76	0.43
	3%	0.35	0.12	0.07	0.84	0.29	0.17	**1.68**	0.58	0.33
	5%	0.22	0.07	0.04	0.54	0.18	0.10	**1.07**	0.36	0.20
Discount rate		**Green roof 100%**								
	0%	0.60	0.24	0.14	**1.53**	0.61	0.35	**3.02**	**1.21**	0.68
	1%	0.52	0.20	0.11	**1.28**	0.49	0.27	**2.50**	0.94	0.53
	2%	0.43	0.16	0.09	**1.04**	0.38	0.21	**2.01**	0.72	0.41
	3%	0.35	0.12	0.07	0.83	0.29	0.16	**1.59**	0.55	0.32
	5%	0.22	0.07	0.04	0.53	0.18	0.10	**1.01**	0.34	0.19
Low/Low means the benefit-cost ratio has been estimated with the low estimates of the benefits and the low estimates of the cost. Low/Medium means low benefits and low costs. A ratio < 1 means that the costs are higher than the benefits and would led to the no-implementation of the policy.										

First the BC ratios vary with the green roof scenarios and with the discount rate. The UHI reduction assumption makes that the benefits varies non-linearly with the temperature. The health, energy and carbon benefits are subject to thresholds temperature which makes the number of days where the benefits is observed different from one green roof scenario to another.

Within each socio-climatic scenario, the variability is high between the different combinations of benefits and costs: from BC ratios lower than 1 which would reject the green roof implementation to BC ratios larger than one. The BC ratios larger than one correspond to case where the estimated costs are low or medium and the benefits are medium to high.

Finally, we do not observe significant difference in the BC ratio between the two socio-economic scenarios: both in the magnitude of the ratio and in the case where the ratio is smaller or larger than one.

- **Benefit-Cost ratio for HHWS in Madrid**

As for the HWWS, tables 21 and 22 report the benefit-cost ratio for the period 2020-2100 for RCP4.5 and 8.5 for the following hypothesis:

1) High, average and low effectiveness of the system.
2) High, average and low cost of the HWWS.

As for the monetary benefits, the lower bound values have been used (VOLY for premature and displaced mortality). Results show always a positive ratio with high expected health benefits if compared with the costs, indicating that the HHWWS is a low regret measure. The ratio increases when the effectiveness of the system increases, while it decreases when the cost of the system increases.

Table 21: Benefit-cost ratio of HHWWS for RCP4.5 and SSP2, period 2020-2100 (VOLY for premature, de Ayala and Spadaro, 2014, and VOLY for displaced, Chilton et al, 2004).

S1 - no acclimatisation, Tcrit constant=34		**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=avg	Effect=low	356	345	333	320	297
HHWScost=avg	Effect=avg	404	392	378	364	338
HHWScost=avg	Effect=high	458	444	429	412	383
HHWScost=low	Effect=avg	1,792	1,736	1,673	1,609	1,491
HHWScost=high	Effect=avg	228	221	213	205	190
S1a - acclimatisation, Tcrit increasing		**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=avg	Effect=low	439	413	386	362	322
HHWScost=avg	Effect=avg	499	469	439	411	366
HHWScost=avg	Effect=high	566	531	497	466	414
HHWScost=low	Effect=avg	2,203	2,069	1,937	1,814	1,613
HHWScost=high	Effect=avg	282	264	247	232	206

Table 22: Benefit-cost ratio of HHWWS for RCP8.5 and SSP5, period 2020-2100 (VOLY for premature, de Ayala and Spadaro, 2014, and VOLY for displaced, Chilton et al, 2004).

S2 - no acclimatisation, Tcrit constant=34		**d=0**	**d=1**	**d=2**	**d=3**	**d=5**
HHWScost=avg	Effect=low	438	411	383	356	310
HHWScost=avg	Effect=avg	497	467	436	405	352
HHWScost=avg	Effect=high	564	529	494	459	399
HHWScost=low	Effect=avg	2,212	2,076	1,934	1,795	1,560
HHWScost=high	Effect=avg	280	263	245	228	199
S2a - acclimatisation, Tcrit increasing						
HHWScost=avg	Effect=low	723	637	556	486	382
HHWScost=avg	Effect=avg	821	724	632	552	434
HHWScost=avg	Effect=high	931	820	716	626	492
HHWScost=low	Effect=avg	3,628	3,194	2,790	2,437	1,916
HHWScost=high	Effect=avg	463	408	356	311	245

- For cost effectiveness analysis:
  Which alternative achieves a defined objective at lowest costs?
  What is the cost-effectiveness ratio?
- For multi-criteria analysis:
  Which adaptation option performs best?
  (e.g. for PROMETHEE approach: which option has the highest net flow?)

- What are the uncertainties associated with the performance of the different options?

The benefit-cost ratio is derived for 5 services of green roofs and we have seen from Table 7 that the list of services is longer. As we add other services, we would reduce the epistemic or knowledge-based uncertainty and this would change the value of the benefit-cost ratio but will not change the ontological uncertainty inherent to the natural variability of the processes. Moreover, a literature review from the non-estimated services tends to show that knowledge gap for the estimation of these services is high.

Then the CBA is sensitive to the socio-climatic scenario: the low mitigation (SSP5 and Rcp85) and the higher mitigation scenario (SSP2 and Rcp45). It is also sensitive to the discount rate as we illustrated it: using 0%, 1%, 2%, 3% or 5% and non-linear discounting will change considerably the costs and the benefits. Then each type of services and costs are estimated with low, average and high parameters: results of the benefits costs ratio are very sensitive to this parameters' range as illustrated in Table 19 and Table 20 .

Moreover, we have seen that the larger benefit is due to health services. This effect is subject to 2 sources of uncertainty: the uncertainty: on the one hand the uncertainty in the epidemiologic relations (health-temperature relationship) and the economic valuation of mortality and on the other hand the uncertainty relative the outdoor temperature reduction obtained from green roofs from which the health service is derived. If the first source of uncertainty has can be reduced with empirical analysis of the literature, the gap reduction of the second source of uncertainty is much more difficult to address as very little experience of green roof contribution to urban heat island reduction exists. Moreover, a critical mass of green roof would be required to obtain such a UHI.

As for the HHWWS there are different sources of uncertainties in relation to the following factors:

1. Changing of Tcrit (threshold temperature), AR (attributable risk) and DMR (displaced mortality rate) can follow different potential paths of evolution over time. The change of Tcrit is analysed through a probability density function based on projections of future daily maximum temperatures under scenarios RCP4.5 and 8.5 (Monte Carlo simulations), and in the CBA carried out for the HHWWS for Madrid just one possible trajectory of evolution as been considered, to simplify the calculations: the one based on the annual mean Tcrit temperature of the random, stepwise Tcrit trajectories assumed in the Monte Carlo simulations (see Fig. 15 and 16). Also for the AR and DMR, among the potential curves of risk evolution and DMR decreasing paths (based on Monte Carlo simulations), the mean curves have been considered (Fig. 17 and 18) for simplicity.
2. Dose-response function and epidemiological limitations (Diaz et al, 2014a and 2014b).
3. Health impact assessment:
   - Displaced mortality has been assumed to be 40% but for sensitivity analysis of the impacts it would be useful to use also an upper bound (see paper of Hajat et al, 2005).
   - Estimation of the years of life lost (LYL): for displaced and premature mortality the mean loss of life over the period 2020-2100 has been used (16 days and 4.7 years per deaths respectively), though for sensitivity analysis the health impacts are estimated using a lognormal distribution (for simplicity the latter is not considered in the calculation of the BCR).
4. Monetisation of the health benefits and values to use (VSL versus VOLY, and reference values for each of them). According to the economic value used, different BCR can be derived. We calculated the BCR for the following cases:
   – VSL for all deaths.
   – VSL only for premature deaths and no value for displaced mortality.
   – VOLY for both premature and displaced mortality.

   Using the VSL for all deaths provides an upper bound of the benefits, VOLY for premature and displaced deaths gives a lower bound, while using VSL only for premature deaths gives a medium estimate for the economic benefits. In the case of the HHWWS for Madrid, however, the BCR is always strongly positive, so the choice of the economic unit for the health valuation does not affect the final results of the BCR (>1).
5. Effectiveness of the HHWWS: the results of the model of Fouillet et al (2008) have been used as a reference of the range values for the effectiveness of the HHWWS in Madrid, for lack of specific data for the system of Madrid.

6. The variable costs of the HHWWS are derived and adapted from a study done by Ebi (2004), while only the fixed costs are specific to Madrid system.

The CBR is sensitive to the climate change scenario (RCP 4.5 versus RCP8.5) and to the discount rate as we illustrated: 0%, 1%, 2%, 3% or 5%.

- Is there and, if so, to what extent uncertainty in the ranking of options?
- Is it possible to determine which option most likely performs best or is it necessary to gather further information to reduce uncertainty (go back to step 4)?

What are the main lessons learnt from your case study?

- transferable results?

The results give an idea of the economy of adaptation in Mediterranean cities which have a specific performance under climate change conditions. The sensitivity of results to climate data makes final results geographically depends. Results could be transferred to similar climate and cities. All the parameters of this model, expect those of water retention services are parameters that were estimated in the literature for Madrid or for Spain.

For the HHWWS, the methodological framework for the estimation of the health impacts, evolution of Tcrit, AR and DMR, as well as the CBA framework could be transferred to other geographical contexts, while the specific values estimated for Tcrit and attributable risk from the epidemiological study cannot be transferred as they specifically apply to Madrid. Each city is characterised by its own Tcrit (at which daily mortality starts to increase significantly), and has a specific attributable risk for mortality.

- lessons learnt with regard to the process of economic evaluation?

Estimating the benefits of green roof in physical terms (ie non-monetary) is a very challenging exercise given the little (but increasing) knowledge on green roofs at meso-scales. The most uncertain one is the urban heat island (UHI) effect reduction. If UHI is well documented for Madrid at spatial scale, the contribution of green roof in reducing UHI is mostly unknown in Madrid, in a single estimation isolated of other adaptation measures like air conditioning reduction (Salamanca et al 2012). The literature review of UHI reduction informs that the higher temperature reduction can be expected when air conditioning is turn off. More generally UHI would be reduced in a more effective way by reducing the causes of UHI like air conditioning than by using engineering solutions like green roofs.
The monetary valuation of the services presents the usual challenges when services are intangible and when limited access to data makes the use of a proxy necessary.

Climate change gives a particular interest to the study as it needs to relate services with climatic phenomenon: rainfall and temperature. The model developed estimates 5 urban services based on temperature threshold and rainfall threshold. For energy consumption reduction, the model uses of the number of days in the future where the maximum temperature is above a given threshold (28ºC). But it is also well know that energy consumption is not linear with outdoor temperature: then cooling a house would cost more when outdoor temperatures increases. Accounting for this effect would require a model where energy savings from cooling are related to outdoor temperature in addition to the indoor targeted temperature. For water retention services, the rainfall pattern also influence the capacity of retention of the roof. The climatic data do not allow such estimation. Considering this daily pattern would maybe change the type of valuation of the services: in addition to a reduction of water treatment, the retention of water on the roof would reduce the flooding of the street during storm events.
Then the choice of extensive green roofs (contrary to intensive roofs) results from their better adaptation to dry climate with water stresses and drought in summer but extensive roofs generate also less services than intensive ones. Accounting for intensive roof would require to account for water needs and water supply in dry climates.

As for the HHWWS, the monetary valuation of the health impacts refers to the well-known measures of VSL and VOLY, which have been extensively debated in the literature. Many economists question the use of these values in CBA on ethical grounds given the uncertainties and biases intrinsic to the valuation methods applied, though many recommendations have been developed to correct for existing limitations. In any case, as stated in OECD (2011), "even if mortality risks are not valued explicitly, they will still be valued implicitly through the decisions that are made" in policy contexts. Therefore, it is preferred to use explicit values (providing clear and transparent information on the non-market methods or benefit transfer techniques) so that to make more consistent policy decisions.

OECD guidelines (2011) recommend to use VSL for valuing mortality risk changes, while VOLY should be used only if based on primary surveys valuing VOLY directly (for which only few studies are available in the literature). In our case study we use both indicators to provide a range of economic benefits, and because we think that VOLY might be more appropriate than VSL to value displaced mortality specifically. Actually, in the case of Madrid, the years of life lost (LYL) for displaced mortality are very low (16 days), meaning that these people would have died regardless the heatwave episode.

The following values have been chosen:

- VSL proposed by OECD (2011) for EU-27, based on literature review and the most comprehensive meta-analysis of stated preference studies (Lindhjem et al, 2010 and 2011).
- VOLY for one month gain in life expectancy in poor health for acute mortality in a context of air pollution (Chilton et al, 2004). We think this study is the most appropriate to be applied in a context of heatwave to value displaced deaths, for the similarities of the background (the LYL are between 1

week and 1 month in poor health for displaced mortality in Madrid) (the choice is in line with OECD guidelines according to which the use of VOLY is justified when based on primary surveys estimating the WTP for the specific change in life expectancy directly).

- VOLY adjusted for VSL/VOLY for people in normal health (de Ayala and Spadaro, 2014) for premature chronic mortality, which accounts for 4.7 years of life lost on average.

With the above values, the following scenarios are proposed:

- VSL for all deaths (which provides an upper bound estimate).
- VSL only for premature deaths (considering that the LYL for displaced mortality are very low). Attaching a VOLY estimate for displaced mortality would not change much the final results, due to the small number of LYL for displaced mortality and the low VOLY (based on Chilton et al, 2004)
- VOLY for premature mortality (normal health, chronic mortality) and VOLY for displaced mortality (one month gain in poor health, acute mortality)

- feasibility of methods?

- important data sources?

Important data sources for the case study are Instituto Nacional de Estadística (National Statistics Institute), Ayuntamiento de Madrid (Madrid Municipality), Instituto Nacional de Meteorología (National Metereologic Institute) and Plan General de Madrid (Madrid Town Plan).

Other sources include Construction Databases form the Technical Architects Association, Building Companies and Experts.

- etc...

Implementation Analysis – Understanding, Leadership and Governance of the implementation of adaptation measures

The aim of this section is to establish whether adaptation measures can be implemented in the real world context of case studies, and what the key obstacles and opportunities are in doing so.

Please answer the following six questions giving specific evidence and examples where possible. In principle all implementation activities should be analysed, i.e. activities supported by BASE partners as well as those by other actors. If it is possible to inform about the implementation of those adaptation measures assessed for task 5.2, it is very important to do so in order to comply with the DoW.

To ensure the answers provided are comprehensive and in line with WP2 and WP7, a checklist is provided below with the main factors that all case holders need to consider. Please read through this checklist and ensure you have discussed in your answers, all those factors that were in some way relevant to the implementation of your case study.

Questions

1. How have climate change adaptation measures and strategies been advanced in the case study? Describe the process! (Minimum 500 words)

2. What drives the implementation process and who enables implementation of adaptation measures and strategies/policies? Please explicitly refer to the factors mentioned in the checklist and be specific about any relevant policies! (500 – 1000 words)

3. What obstacles were encountered to implement adaptation measures and strategies/policies? Please explicitly refer to the factors mentioned in the checklist and be specific about any relevant policies! (500 – 1000 words)

4. If any obstacles were overcome, how was this achieved? (Minimum 500 words)

5. What are the future prospects of the climate change adaptation activities in the case study? (200 – 500 words)

6. What is the key message from this case study (and which could work in other cases as well)? Don't forget to consider any specific policy recommendations that arise in your case study! (200 – 500 words)

Checklist

When answering the above questions ensure you consider each factor listed in the checklist below that might have had a role to play in the implementation of your case study; please mark in the table what factors you have covered in your answers. The checklist might not be all-inclusive, so feel free to discuss other factors that might not be listed. Mark 0 – 5 (0 being not relevant and 5 being extremely relevant), or not applicable (N/A)

Checklist	
Specify sectors covered *(e.g. coast, city, agriculture)*	Water, Health, city
Specify adaptation measures covered *(e.g. altering cultivation practices, building defences; explain why they were chosen)*	Reuse of urban water Water rights exchange programmes Heat-health warning systems Green infrastructures: trees in the street, parks, green roofs
Specify climate change impacts covered *(e.g. flooding, heat stress, sea level rise)*	Heat stress, water shortage
Specify main results of activities *(e.g. changes, outputs)*	
Key factors influencing implementation:	**Mark as: 0 – 5, or N/A**
i. **Knowledge and information about climate adaptation**	4
ii. **Actors** (e.g. leadership, perceptions, understanding of climate adaptation, participation, decision making, stakes, conflicts/synergies)	4
iii. **Framing of climate adaptation** (e.g. as sustainability concern, (urban) planning or environmental issue, disaster risk mitigation topic)	3
iv. **Local and regional context** (e.g. culture, history, geography, environment, economy)	2
v. **European, national, regional and local regulatory framework** (e.g. be specific about laws, strategies, policies)	2
vi. **Institutional context** (e.g. integration of adaptation into existing structures/activities/strategies, decision making, conflicts/synergies, governance arrangements, incentives for engagement)	4
vii. **Resources** (e.g. financial, human)	5
viii. **Nature of adaptation measures** (e.g. no regret, flexibility, important co-benefits, side-effects)	3
ix. **Other** (specify ______________________________)	

Development of new tools for adaptation planning and implementation

(Please describe the development and use of new tools for climate change adaptation planning and implementation which you have used under BASE research project and report on their SWOT analysis and overall feedback. Máx 2000 words)

New tool(s) developed and used during BASE:

A three phases participatory process engaging stakeholders, experts and citizens, at three different scales: National, Regional and Local.

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Description for each New tool (Máx 50 words/each):

SWOT Analysis:

Strenghts	Weaknesses
- Collect data from the main sectors affected - Learn from ongoing adaptation strategies already implemented - Identify synergies and trade-offs between sectors - Direct contact to stakeholders' knowledge - Collect data from the main sectors affected - Learn from ongoing adaptation strategies already implemented or planned - Identify synergies and trade-offs between sectors - Identify unintended (negative or positive) impacts of adaptation policies	- The results (the most beneficial adaptation options) are not going to be implemented in the short term - Access to data related to costs could be limited (review in a later stage)

Opportunities	Threats
- Strengthen knowledge - Share knowledge between sectors - Raise interest towards climate change	- Give excessive weight to experts and practitioners

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