RAMSES

Science for cities in transition

RAMSES Project

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KEY MESSAGES

1. **An extended assessment of over 500 European cities shows that many cities in Europe face increased climate-related risks.** An EU-wide assessment of key vulnerabilities and climate risks has provided new insights into which regions will be most acutely at risk in future as a result of climate change.
2. **The heat burden in cities is expected to increase tenfold by the end of the century.** The effects of heat waves are exacerbated by soil sealing and by urban spatial design, while they can be relieved by city greening measures, awareness-raising and behavioural change, especially among the most vulnerable urban populations.
3. **When the sea level rises, damage costs to cities rise even faster.** The RAMSES project developed a new methodology that can estimate the damages resulting from sea level rise in over 140 European coastal cities. Appropriate adaptation measures protecting cities from coastal flooding can provide significant savings on damage costs.
4. **New methodologies can help provide much-needed evidence of the costs of climate change and the costs and benefits of adaptation measures.** RAMSES has developed transferable economic methodologies that calculate estimated production loss costs from climate hazards, as well as health damage costs. These show the vulnerability of different economic sectors to climate change and the key causes of production losses.
5. **Heat-related productivity losses depend on a city's economic structure.** Research showed that the magnitude of temperature increase is not the only factor determining the extent of productivity loss due to intense heat, but the sector structure is also relevant.

INTRODUCTION

Cities are arenas in which multiple complex systems and sectors intersect and intertwine. This complexity requires governance structures and decision-making processes that do not only respond to immediate challenges but also work towards on long-term goals. In fact, by thinking strategically and fostering sustainability transitions, cities can realise their tremendous potential for transformation, exploiting co-benefits and empowering innovative co-creation schemes between different actors.

In order to prevent the consequences of a fast changing climate in time, cities need to team up and learn from each other. While continuing to reduce GHG emissions to keep global warming at a manageable level, cities will need to adapt to tackle the effects of and reduce the damage and the costs resulting from climate change. Cities need evidence of specific alternative policies' effectiveness in order to support this effort and to gain political commitment to it. This is why a concise assessment of potential economic consequences is a crucial support tool for decision-making. Cities need to be able to demonstrate the economic consequences of inadequate or inappropriate action in the face of climate change and they also need to be able to demonstrate the benefits of various adaptation measures. The RAMSES project aims to provide cities with this much-needed evidence, thus supporting their transitions towards a better-adapted and sustainable future.

This policy brief is an output of the EU FP7 project RAMSES - Science for Cities in Transition. It summarises the key findings of the project, highlights their implications for adaptation strategies and measures, and points to research that could facilitate enhanced adaptation decision-making. It also provides policy recommendations regarding some of the most pressing issues related to adaptation to climate change.

The full RAMSES project reports, which elaborate on the topics mentioned in this policy brief, can be retrieved from **www.ramses-cities.eu/resources**.

KEY FINDINGS

EU-wide assessment of key vulnerabilities and priority risks for urban areas provides useful insights for risk management and on how to prioritise adaptation investments

The question of how global climate change will impact cities is raising increasing concern. In order for cities to develop a suitable adaptation strategy, they first require an adequate risk assessment, taking natural hazards as well as socio-economic vulnerabilities into account. To this end, RAMSES has developed a methodology for a detailed and threat-related climate risk analysis.

The approach takes advantage of an increasing availability of European and global datasets and computing power to apply the method to 571 cities in the EU's Urban Audit database. The results provide information on hazard, exposure, vulnerability and risks and can be used by national and EU policy makers to inform investment prioritization for particular risks and across European regions. Furthermore, by assessing the components of risk separately the results provide important insights into the nature of appropriate adaptation strategies – whether to focus on engineered adaptation and/or strengthening socio-economic capabilities.

The top-down approach provides a broad overview of relative risks across cites in the EU, which should then be substantiated by local risk analysis – which are also being developed in RAMSES. The results of the exposure and vulnerability assessment can be summarised as follows:

- The distribution of vulnerabilities to both heat and drought risks as well as to floods (all types) is driven by morphological, demographic, economic, social factors, as well as by awareness and commitment.
- Heat and drought risks are significant in a number of locations. Typically, Southern European cities are more likely to be exposed to significant drought risk than those in Northern Europe. Therefore, drought risk management should be of high priority for those cities.
- Heat wave risk is relatively high for mid-latitude European cities, mainly in the Danube and Rhine basins, in France and in Northern Italy.
- Pluvial and fluvial flood risk presents no clear spatial distribution, as this very much depends on local contexts and morphologies.
- UK cities are expected to experience some of the greatest impacts in terms of changes in fluvial flooding.

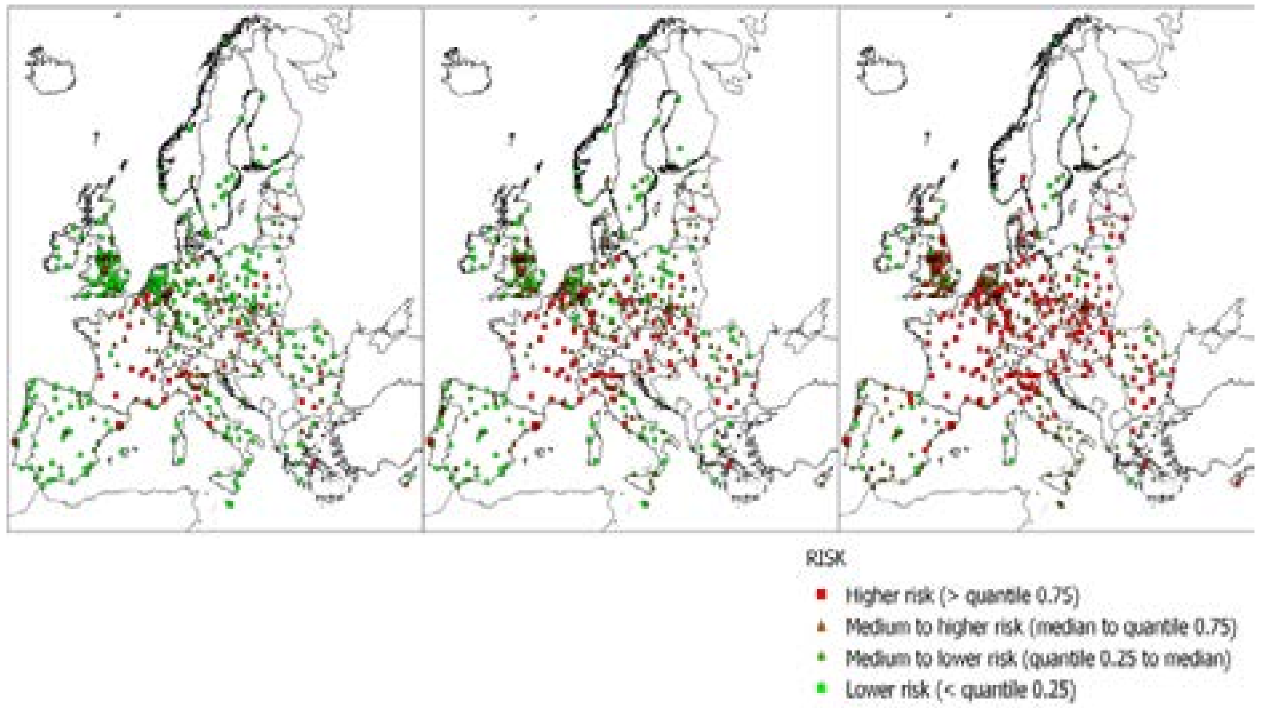

Figure 1: Relative heat wave risks, accounting for changes in heat wave hazard and socio-economic factors, across 571 EU cities

Cities need to prepare for heat waves

In addition to drought and flooding, extreme heat stress is perceived as a problem that may increase considerably if no action is taken. Indeed, climate projections indicate that extreme heat waves, such as the one that occurred in 2003 in Europe are expected to become more commonplace towards the end of the century. Additionally, cities experience enhanced heat stress because of the urban heat island (UHI) phenomenon. Yet, little or no information is available regarding the future urban climate. In particular, there is a lack of climate projections at the scale of urban agglomerations, partly because fine-scale climate models are so technically complex. However, policy-makers and city stakeholders urgently need this support to be able to take informed climate adaptation action.

RAMSES conducted assessments of the climate conditions in the cities of Antwerp, Bilbao, London, Rio de Janeiro, Hyderabad, New York, Skopje, Berlin and Almada. This was done by combining the newly developed UrbClim model with Global Climate Models and conducting extended simulations for present (1986-2005) and future (2081-2100) climate conditions. It was found that:

- Based on the results of the present period, overall and consistently within the city sample considered, urban areas experience twice as many heat wave days as their rural surroundings. This is problematic, as in most countries, the so-called ‘heat health action plans’ are triggered using rural temperature forecasts only.
- By the end of the century, the number of heat wave days is expected to increase by a factor of nearly ten. This means that several cities are expected to face one month or more of heat wave phenomena each year.
- Assessing 102 cities throughout Europe, it was shown that the average UHI of these cities is consistent with population density and mean regional wind speed.
- Cities in Central and Eastern Europe are especially at risk when it comes to enhanced heat stress. In fact, these are the areas in which climate models project a significant increase in summer temperatures, with serious potential health implications. For instance, the project’s estimates suggest that in the absence of adaptation, heat-related mortality in Skopje may more than double in 2026-2045, and more than quadruple in 2081-2100.

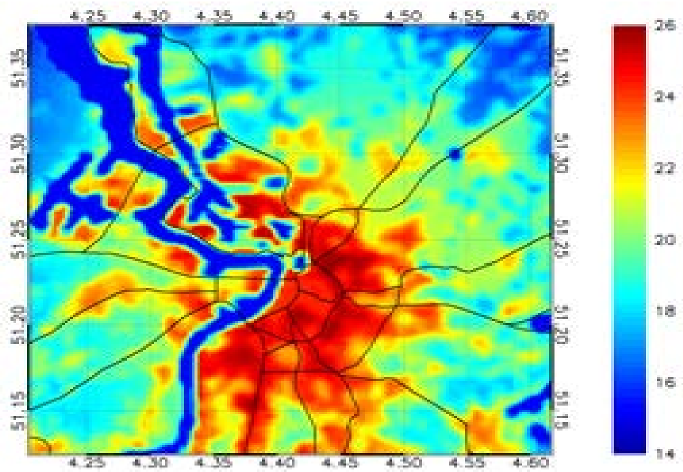

Figure 2: Expected average number of heat wave days per year for the period 2081-2100 for the Antwerp area under IPCC scenario RCP8.5. The values shown are about a factor of ten higher than what is currently observed.

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Green infrastructure is key to reducing the Urban Heat Island (UHI) Effect

The UHI effect is caused by the replacement of natural land cover by dense concentrations of concrete (e.g., in buildings, pavements, roads) that absorb and retain heat. While it is well known that green infrastructure positively affects the urban climate while at the same time providing multiple additional benefits, more detailed information on its adaptation effects is needed. Applying an advanced modelling approach for the cities of Antwerp, Paris and Delhi at the mesoscale (i.e. the entire city with all its parts) and for the cities of Antwerp and Bilbao at the microscale (i.e. city quarter, square, urban canopy street), RAMSES research showed that:

- Trees, green roofs and vegetation can help reduce the UHI effect by shading buildings, deflecting radiation from the sun and evaporation.
- At the city scale, the effect of vegetation on thermal comfort appears to be limited, unless the percentage is radically increased. Nevertheless, vegetation has strong potential to reduce the UHI risk both at the very local level and in nearby areas, especially due to its effects on thermal comfort.
- In terms of the cooling effect, larger parks appear to be preferable to small parks. However, the presence of smaller parks might be important at local scale in order to create cooling spots during heat waves.
- Tree-lined streets are more effective overall at reducing the UHI than green roofs due to their larger vegetation volume and foliage density, as well as their provision of shading.
- A lower temperature increase is expected in areas characterized by a high roughness length (forests and urban parks) than in areas of low roughness length (grassland and cropland).
- Urban canyons play an important role in defining the city’s microclimate and thermal comfort in outdoor spaces. The ratio and orientation of urban canyons influence thermal comfort at pedestrian level.

Figure 3: Visualization of tree-lined streets in compact low-rise, compact mid-rise and open-set high-rise urban areas in Bilbao, Spain

Resilient architecture and infrastructure indicators and design guidelines are key for a more adaptive urban environment

In order to understand whether measures developed in response to climate change are effective, clear indicators for monitoring and evaluation are needed. Cooperating with city stakeholders of eight case study cities, RAMSES scientists developed a significant contribution to a detailed taxonomy of indicators and design guidelines for resilient architecture, infrastructure and urban environments.

The methodology can be applied by public authorities at the building, neighbourhood and city scale to develop climate resilient infrastructure focusing on structural and physical adaptation options for blue, green and grey infrastructures. The taxonomy of adaptation measures and the corresponding indicators allow stakeholders a flexible and customizable use.

Estimating economic costs of climate change in European cities is a key resource for local policy-makers

In the context of limited resources and competing priorities, evidence of the economic consequences of different climate hazards as well as of the costs and benefits of adaptation measures is urgently needed. RAMSES has developed a comprehensive review of existing estimations of climate change and adaptation costs for European cities. This is accompanied by an economic cost methodology to assess the impact of specific climate hazards that are affecting urban areas.

The methodology is particularly effective as a result of the following characteristics:

- its intermediate level of complexity;
- its transferability across cities in Europe and the world with minimal need for economic data;
- its ability to take cities' specific characteristics into account.

It can be used to understand different economic sectors' vulnerabilities as well as the key mechanisms causing production losses. It also helps to identify the most effective climate change adaptation measures or economic recovery plans for specific cities. This methodology thus comprises part of a framework for understanding vulnerability at the European and global levels in terms of cities' economic productivity.

One of the main advantages of this economic cost methodology is that it can estimate averted losses (adaptation benefits) for direct comparison with benchmarked damage costs without adaptation. In terms of heat burden, comparable averted losses can be estimated for a wide range of adaptation measures such as behaviour change, mechanical ventilation, insulation and solar blinds.

RAMSES scientists found that not only the magnitude of future temperature increase, but also the economic structure of a city determines the extent of productivity loss due to intense heat. For example, the costs of productivity losses in London are estimated to be substantial, but in relative terms –i.e. as a percentage of total GVA – lower than in Antwerp and Bilbao (in the period 2081-2100 the total GVA loss in London is estimated to be 0.4% while in the same period it is estimated to be 2.1% in Antwerp). This is due to a combination of lower temperatures and an economic structure that seems less vulnerable to heat because of a relatively low labour intensity.

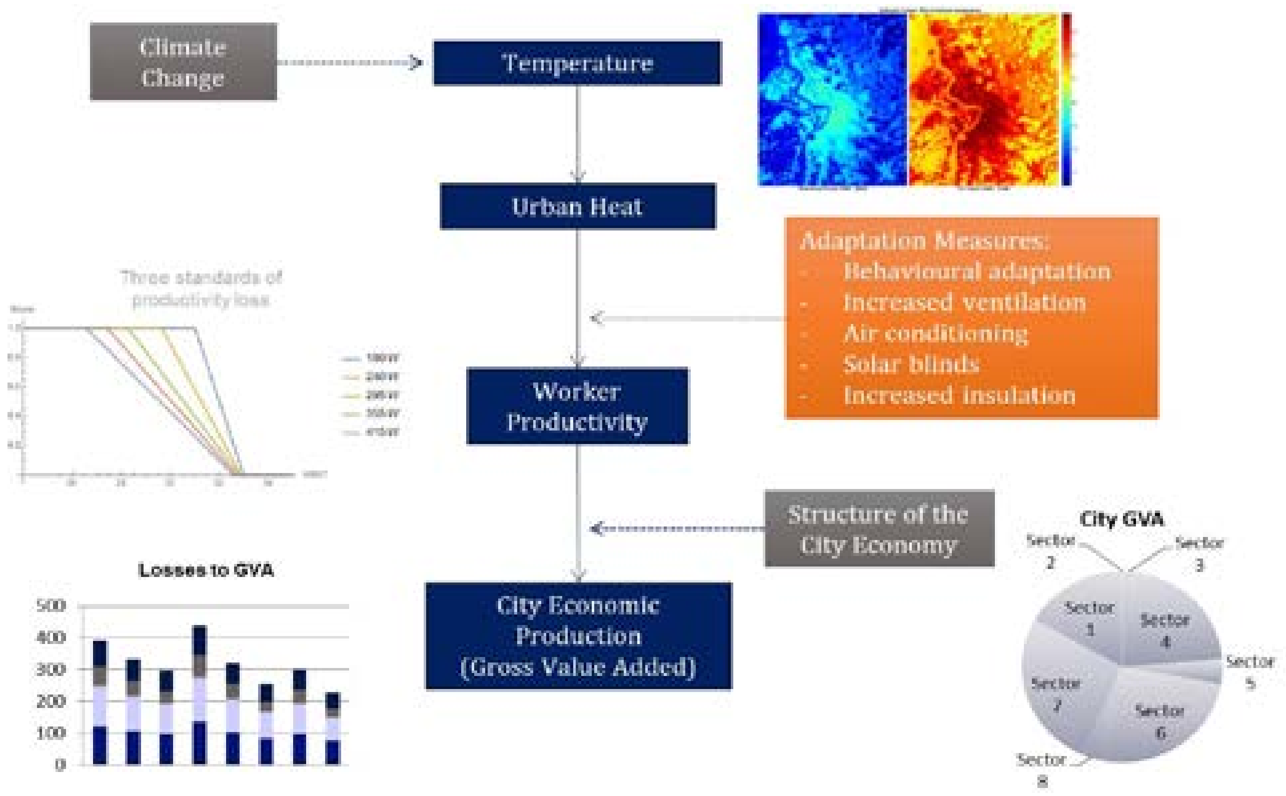

Figure 4: Overview of the methodology

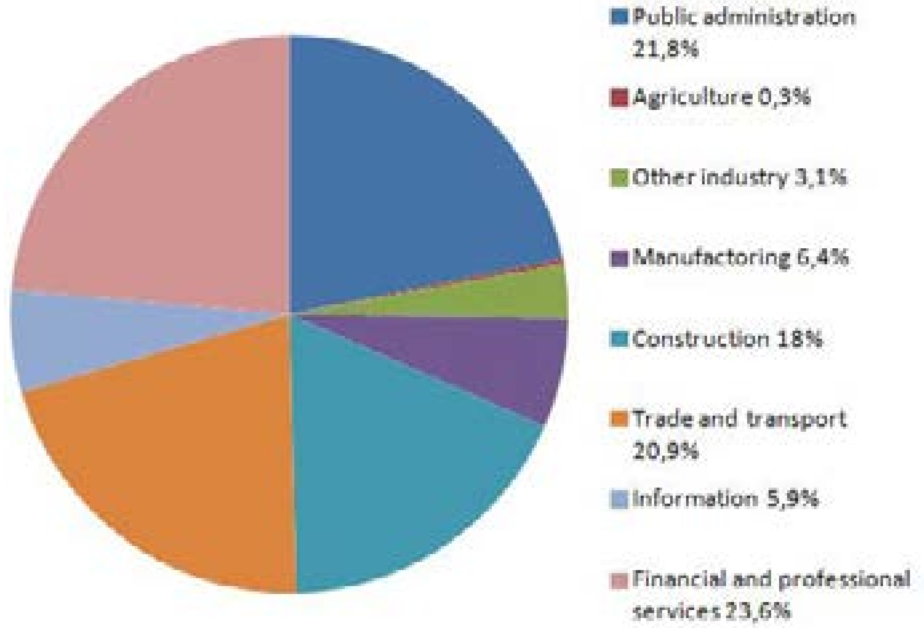

Figure 5: Heat-related losses by sector in London in a warm year in 2081-2100 (percentage of total loss)

When sea levels rise, damage costs rise even faster

Damages from extreme events like floods are even more relevant than the mean sea level itself when it comes to the costs of climate impacts for coastal regions. However, while it is now rather well understood how sea-levels will rise in the future, the RAMSES project has made an important step forward to calculate damage costs for cities during the next decades. The project now provides a method to quantify monetary losses from coastal floods under sea-level rise. The main result is that the damage costs consistently increase at a higher rate than the sea-level rise itself.

Figure 6: Flood defense measures can counteract an increasing flood risk. Image copyright: Exeter Flood Defenses (photo on Flickr) by "Nathan Hadley", licensed under CC BY 2.0

Rising sea levels as a major impact of climate change pose a risk for coastal regions – the mean regional sea level rise takes effect by more frequent and more intense coastal flood events. At the same time, the severity of flood impacts is not only determined by environmental factors, but also to a significant extent by human decisions: flood defense measures can counteract the increasing flood risk. The study illustrates that the complexity of climate change, adaptation, and flood damage can be disentangled by surprisingly simple mathematical functions to provide estimates of the average annual costs of sea-level rise over a longer time period.

The scientists developed a method to translate the probability of flood events occurring into the probability of inundation damage. Expected regional sea level rise is taken into account by separating two components, namely the increasing number of events and the increasing severity of each one. Moreover, potential flood defense measures like dikes or sea walls can be included into the calculations as they prevent or mitigate damages from storm surges.

Although coastal cities are different around the world and although flood-related threats have different characteristics on different coasts, the team found some overall trends to be true. The equations were found to work in Mumbai, New York, Hamburg, so as applies to the Pacific, Atlantic, and North Sea respectively. The scientists tested the method by applying it to the Danish city of Copenhagen. It was found that if no action is taken, a moderate mean sea level rise of 11 centimeters between now and mid-century would in the same period double economic losses in the city.

Climate change affects citizens' health creating various negative cascading effects on the economy

Climate change has already affected human health over the last few decades, both directly by changing weather patterns and indirectly by shifting patterns of disease transmission and disrupting basic elements of health such as safe drinking-water, clean air and food security. Besides their inherent human costs, ill health and premature mortality represent real and significant economic costs to society. Economic evidence on the health impacts of climate change is increasingly important to provide a basis for a fair assessment of priorities in the allocation of resources, to support local decision-making and ultimately to advance climate adaptation.

Though health impacts cannot be fully represented in economic terms, it is possible to provide estimations of these costs. For this purpose, RAMSES developed a tool which can be applied both prospectively and retrospectively. The methodology suggested for the evaluation of economic consequences of disease and injury resulting from climate-related health outcomes consists of four steps:

1. Calculate the economic cost of the health impacts considered, including the cost of premature mortality, the cost of additional healthcare and the cost of lost work days associated with illness;
2. Calculate the cost of health adaptation, that is, of the interventions planned and necessary to avert or minimize the health impacts considered;
3. Estimate the economic benefits of such interventions, by monetizing the avoided cases of the health impacts considered; and
4. Choose and report against indicators needed for planning and decision-making, such as cost-effectiveness estimates and benefit-to-cost ratios.

The tool is based on a limited number of inputs, which makes it applicable even in cases where little data is available.

Figure 7: Extreme heat stress in the city can be reduced by increasing vegetation, tree lined streets and green roofs. Image copyright: heat wave in bryant park (photo on Flickr) by "Lempsipmatt" licensed under CC BY 2.0

Making use of the transformative potential of climate adaptation unlocks co-benefits and supports the transition towards sustainability

Climate change often exacerbates existing problems, thus adaptation presents an excellent opportunity to rethink and tackle present and future challenges from a new and holistic perspective. Different approaches to climate adaptation can be distinguished:

- The system is adjusted to the new conditions (incremental).
- Social and political vulnerability is reduced, altering the rules and decision-making processes, but keeping the norms and principles that governed the rules (transition).
- The vulnerability is reduced through a political regime shift that will change the existing system altogether (transformation).

RAMSES scientists have created a library of standardised adaptation and transition functions, which describe the likelihood of undergoing a transition given several influencing factors. This can be used to facilitate city processes and help decision-makers to estimate adaptation costs in a variety of urban sectors and cities in transition.

These adaptation and transition functions form an integrated conceptual framework for transition in urban areas. This framework consists of:

- a system map where the impacts of climate change on the urban system are analysed and the key problems are detected;
- a selection of adaptation options where the options are defined, assessed and prioritized;
- a definition of planning and implementation options where "how", "when" and "by whom" is defined through an adaptation pathway approach.

The entire process enables the design of adaptation strategies that consider the triggers of change towards a transition.

RAMSES research emphasises that despite increasing levels of awareness of the causes and impacts of climate change, many institutional, regulatory, structural, behavioural, cultural, and contextual obstacles to effective and efficient climate adaptation action exist. Based on the analysis, the main findings and recommendations can be summarised as follows:

- A combination of top-down and bottom-up approaches is the best option for adaptation in urban areas.
- In assessing vulnerabilities and designing viable adaptation solutions, factors such as values, cultural context and norms of specific societies must be taken into consideration.
- The triggers of change or transition factors should be tailored to respond to the obstacles detected for each phase of this adaptation process. These include, among others: public consent and political leadership in order to achieve innovations and change (both must be ensured in the long term); education and awareness (accessibility of data and the ability to use them is key for this); enhanced public-private interfaces and participation of a broad range of actors and institutions; and an multi-level governance that goes beyond adaptive planning.
- A successful transformation towards resilience must be cross-sectoral, cut across vertical levels of government and needs to be based on a long-term vision. To achieve a formulated vision, complementary long and short-term targets need to be identified and formulated. Therefore, regulations should be incrementally upgraded to factor in adaptation and resilience priorities.

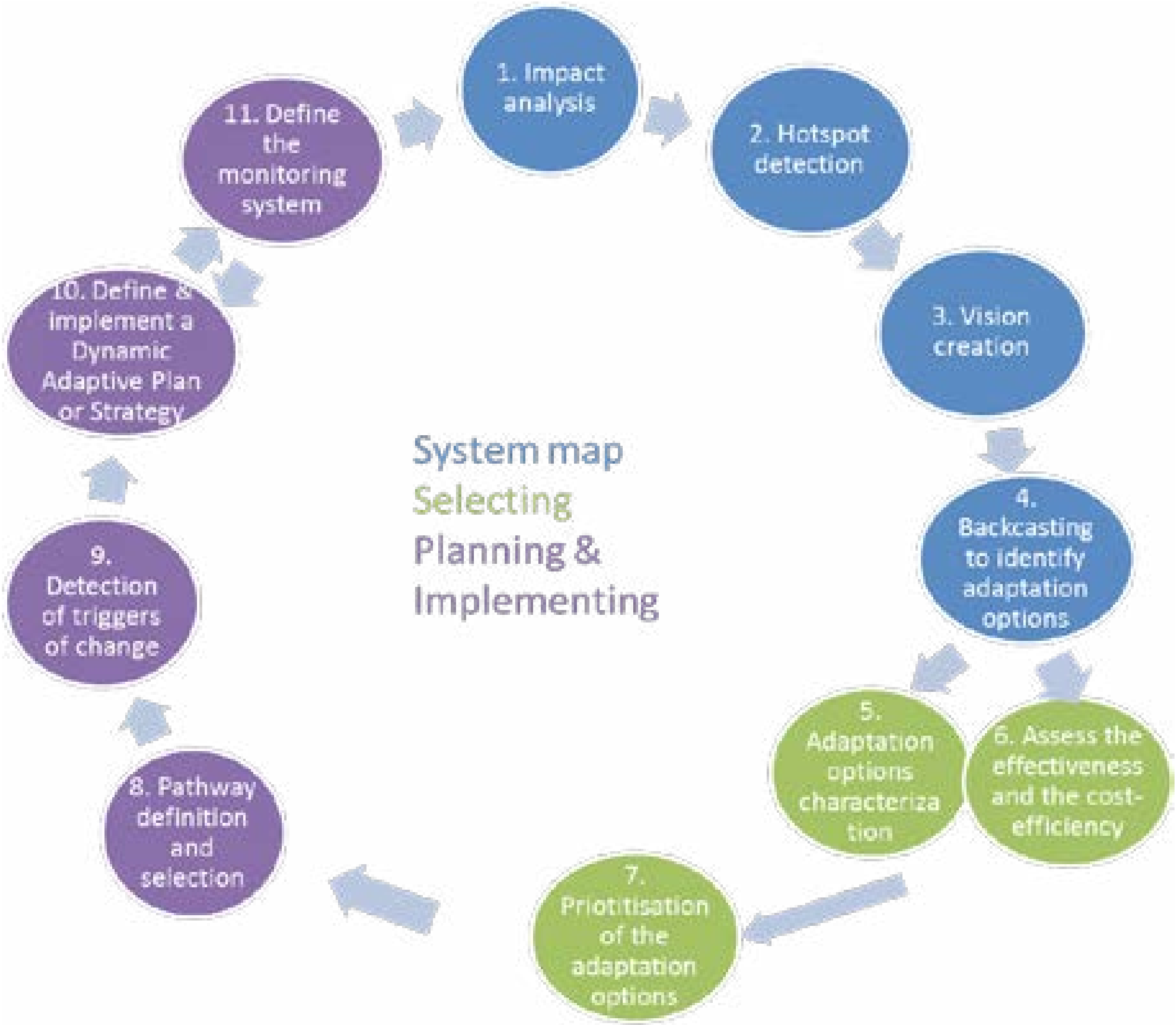

Figure 8: The Dynamic Adaptation Cycle for transformation used by the RAMSES project

WHO ARE THE RAMSES PARTNERS?

RAMSES is a European funded project currently consisting of 12 partners. These are the Potsdam Institute for Climate Impact Research (PIK), the London School of Economics (LSE), the University of Newcastle upon Tyne (UNEW), Vlaamse Instelling voor technologisch Onderzoek n.v (VITO), Université de Versailles Saint-Quentin (UVSQ), Fundación Tecnalia Research and Innovation (TECNALIA), Norges Teknisk Naturvitenskapelige Universitet (NTNU), the World Health Organization (WHO Euro), T6 Ecosystems S.R.L. (T6 Eco), Seneca Group S.P.R.L (SENECA), ICLEI – Local Governments for Sustainability, and the Climate Media Factory UG GmbH (CMF). The Institut Veolia Environnement Association (IVE) and Institut de Recherche pour le Developpement Durable et les Relations Internationales (IDDRI) were previously partners in the project.

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