Executive Summary

The ECONADAPT project has developed a policy-led approach to frame the research and policy analysis, and then focused on the practical application of adaptation economics to near-term adaptation decisions which have short- and/or long-term decisions. This includes low-regret options and iterative risk management.

The project has collated the knowledge base on the costs and benefits of adaptation. This evidence has evolved significantly in recent years, with a greater coverage of risks, sectors and countries, though important gaps remain in many areas. More recent studies show the importance of considering uncertainty, as well as policy implementation costs.

The project has made methodological advances in a range of areas. It has developed adaptation economic methods for assessing adaptive capacity, undertaken primary survey work to understand public preferences for adaptation, and developed methods for the scaling, transfer and aggregation of cost and benefit values. The project has also applied decision making under uncertainty to adaptation economics, reviewing and producing summary information on methods, and undertaking example applications.

The ECONADAPT project has applied these methodological advances to a series of policy domains, focusing on the major priorities for adaptation economics over the next decade.

It has considered the bottom-up costs and benefits of addressing early increasing disaster frequency from climate change, and complemented this with analysis of the fiscal consequences of climate change exacerbating current national level disasters.

It has developed guidance for economic project appraisal, focusing particularly on infrastructure, and undertaking practically focused case studies that consider both river flooding and sea-level rise.

It has also developed guidance for policy appraisal (impact assessment), looking at the development of mainstreaming with a case study in the agriculture sector. A key focus in both the project and policy appraisal studies has been to include decision making under uncertainty.

The project has looked at the wider economic effects of both market-driven and planned adaptation, undertaking macro-economic modelling to assess economic consequences of adaptation from a top-down perspective.

It has also developed the project and policy appraisal frameworks for application in the developing country context, particularly in relation to international climate finance, and undertaken a series of practically focused case studies that demonstrate economic appraisal in developing country contexts.
Finally, the project has compiled this information, methods, insights and guidance into a web-based library and policy toolbox (www.econadapt.eu).

Summary Description of the Project Context and the main objectives

The need for an economic rationale for adaptation is recognised within the EU (European Commission, 2009) and globally (Copenhagen Accord, 2009). The EC states that "Although more specific information on the costs of adaptation is needed...the costs of taking action to address climate change (including mitigation and adaptation measures) will be much lower than the costs of inaction over the medium to long term."[1] This project seeks to provide evidence to help inform action on this basis. Furthermore, a justification for public and private adaptation action is increasingly required, as the economic and financial crises continue and budgets are further constrained[2]. However, the economics of adaptation remains in its infancy, in relation to the methodological challenges and examples of practical application (Markandya and Watkiss, 2009). This partly arises from the uncertainties introduced when considering management of climate change risks, which are of a different order from those conventionally addressed in economic decision-making. It is also a function of the longer time periods relevant to the adaptation context and the impact of these on future values, the challenges of defining the opportunity costs of adaptation relative to mitigation and development, and the inclusion of distributional issues in economic assessment. Thus, whilst adaptation costs are most commonly derived for an" If-Then" framework (also known as predict-and-optimise), where a single scenario is assessed and the costs and benefits of adaptation to this scenario calculated, the recent adaptation literature reflects a growing awareness of the usefulness of iterative adaptive management approaches which focus on achieving robustness, and putting adaptation within a decision framework that seeks to learn and evolve over time (IPCC, SREX, 2012; Downing, 2012).

Further, current economic assessments of adaptation are generally limited to considering the forms of hard, engineering-based, adaptation actions traditionally subject to appraisal, such as dykes. However, the wider adaptation literature emphasises the fact that in most contexts, a much wider range of types of adaptation, including capacity building and soft (non-engineering based) measures, e.g. water conservation measures at a community level, are often much cheaper than engineering based options (Agrawala et al, 2011), and offer wider co-benefits. It is also recognised that climate change risks, particularly under high-end climate scenarios, may require adaptation to be framed in a system-wide analysis, in which transformative actions introduce change at a larger scale or that areas' economic activities and shift locations (Kates et. al. (2012)). In addition, there may be wider macro-economic changes from adapation that influence economic growth and employment patterns. Further, there is an increasing need to consider autonomous adaptation, e.g. automatic adjustments in markets or management, and the costs and benefits of these, noting such mechanisms have potential to offset negative climate change impacts, but also take advantage of positive ones (cf. IPCC 2007[3]).

Set against these issues, the current focus on estimating and compiling engineering based adaptation costs is insufficient. Moreover, the literature that does exist is insufficiently focused on meeting the needs of decision-makers, being primarily

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0147:FIN:EN:PDF
[2] http://ec.europa.eu/clima/policies/finance/budget
[3] http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch5s5-5-1.html

undertaken within an abstract and theoretical framework, which does not ground assessments in existing sectoral policy and appraisal and without stakeholder engagement. In turn, key decision-makers often lack the capacity to apply evidence to inform adaptation strategies because they have insufficient access to information about best practices, and costs and benefits at the relevant scale.

The ECONADAPT project addresses these limitations by developing and providing a range of methods, tools, processes and data outputs to the wider user community, to ensure economic analysis is more effectively integrated in policy decision processes at scales ranging from the local to the international. Moreover, it has developed methods to ensure consistency between analyses at different spatial and temporal scales so that comparison of economic measures can be made and aggregation/disaggregation can more readily be undertaken, and uncertainties are reduced. A critical theme of the project is to support the application of adaptation economics in the period following the publication of the EU's 2013 Adaptation Strategy, focusing on key decision areas that need enhanced economic information, and on the key users of such information. Key decision areas include: management of extreme weather events modified by climate change as these have high impact costs in the short term; appraisal of projects where the costs of climate risks are borne over long time periods; appraisal of flows of large-scale EU funds where the case for climate resilience needs to be made; macro-economic effects of climate change risks and adaptation strategies at Member State and EU levels, and; appraisal of European overseas development assistance aimed at reducing the damage costs of climate risks in less developed countries.

The project has worked intensively with stakeholders from e.g. relevant DGs and European institutions, Member States, Regional and local organisations, and has learnt from, and informed, experience. A two-tier approach has been adopted so that the detailed guidance and empirical data for economists or organisations with adaptation needs is complemented with 'light-touch' methods that can be used by a much wider group of users to help in scoping decision making outcomes. To facilitate dissemination, a strong link has been made with the European Climate Adaptation Platform[4] (Climate-ADAPT), and other boundary organisations, to help reach a wide range of users.

The over-arching objectives of the ECONADAPT project are to advance the knowledge base relating to the economics of adaptation, and to convert this new knowledge base into practical material to help support adaptation planning and decision makers. The project has sought to achieve these outcomes by working with policy makers to learn and co-develop outputs, and ensure that the research is grounded in practice. This should encourage on-going dissemination and transferability of the information in a user-orientated form that is suitable for targeted end users, and help strengthen the impact of the project.

The overall project objectives were.

- To focus on user needs, defined by stakeholder involvement throughout, that inform the methodological and empirical advances to be made;

[4] http://climate-adapt.eea.europa.eu/

- To embed economic assessment within a framework that incorporates the interaction of adaptation decisions within existing policies, current policy developments and other socio-economic trends;

- To derive new and improved estimates of key economic parameters likely to influence economic assessments of adaptation, including those relating to social preferences across time and space;

- To develop approaches that better encourage and facilitate consistency in the treatment of scale, uncertainty, aggregation and transferability in various forms of economic assessments of adaptation;

- To develop and test fit-for-purpose methodological approaches for cost and effect/benefit estimation in adaptation economic assessment, including non-monetary metrics;

- To facilitate the expansion - compared to previous economic analyses - of the range of adaptation actions, and types of costs and benefits considered, in analytical practice;

- To apply the range of methods and data derived in decision contexts where the economic costs and benefits of adaptation are significant, and where the results have high spatial transferability;

- To facilitate effective dissemination of methodological outputs.

The address of the project public website: http://www.econadapt.eu

A description of the main results

WP1 Framing of policy-focused economic analysis

Work Package 1 Objectives
The objectives of this WP are to:
• Establish the overall policy-focused framework for the project and provide key building blocks for the subsequent WorkPackages.

To support this, sub-objectives are:
• To establish stakeholder engagement, co-ordination and the undertaking of a survey of stakeholder needs for adaptation economics.
• To identify the current knowledge gaps that exist in the costs and benefits of adaptation.
• To establish principles of policy-led analytical framework.
• To develop and integrate adaptation narratives/scenarios and climate data products for use in EU & MS adaptation assessment.

The overall aims of WP1 were to establish the overall framework for the ECONADPT project and to provide the key building blocks for the subsequent work packages. A key part of this work package was to engage with and consult policy stakeholders. The WP started with a review of how to undertake stakeholder engagement and consultation in the project. This led to a focus on science practice interaction. The findings of the review were used to develop the stakeholder methods and engagement plans for the study.

Review and gap analysis on the costs and benefits of adaptation
This task aimed to collate information on the costs and benefits of adaptation. During the period, an extensive literature review was undertaken of the academic and grey literature. This identified over 700 relevant papers and reports on the economics of adaptation. These references were reviewed and entered into an electronic inventory, with key classifications added to allow search functions. The library is available at: http://econadapt-library.eu/.

Alongside this, an updated synthesis of the new evidence base on the costs and benefits of adaptation was compiled, using the data inventory. This information was summarised as an input into the UNEP Adaptation Gap Report (2015), and as a chapter for an OECD book on Climate Change Risks and Adaptation: Linking Policy and Economics, published in July 2015. Alongside this, the information from the synthesis was compiled into an ECONADAPT policy brief, which was also published in July 2015. An analysis of this literature reveals that the information base on the costs and benefits of adaptation has significantly grown in recent years. There is a wider coverage of risks as shown in the table below, and geographical area and spatial scale.

Coverage of Cost and Benefit Estimates by Sector in the Adaptation Literature

Risk / Sector	Cost estimates	Benefit estimates
Coastal zones and coastal storms	✓✓✓	✓✓✓
Floods including infrastructure	✓✓✓	✓✓
Agriculture (multi-functionality)	✓✓	✓✓
Water sector management including cross-sectoral	✓✓	✓
Over-heating (built environment, energy and health)	✓✓	✓
Other infrastructure risks	✓	✓
Other health risks	✓	✓
Biodiversity / ecosystem services	✓	
Business, services and industry	✓	✓

✓ = limited evidence; ✓✓ = moderate body of evidence; ✓✓✓ = good body of evidence

There are some major gaps that remain in the coverage, notably on biodiversity and ecosystem services, business/industry, and cross-cutting adaptation. Nonetheless, this new evidence base provides an increased opportunity for sharing information and good practice. An analysis of this literature also reveals important insights:

- The methods for identifying options and assessing costs and benefits of adaptation are changing. The focus of more recent studies has been on early low-regret options, with a greater range of options including capacity building and non-technical options. Some recent studies are also using decision making under uncertainty, using new economic appraisal approaches.

- More recent policy-orientated studies indicate higher costs of adaptation than the previous literature (for like for like measures). This is because they include existing policy objectives and standards, consider multiple risks, recognise and plan for uncertainty and include the additional opportunity and transaction costs associated with policy implementation. The new literature does, however, identify many early low-cost options and alternatives to engineered adaptation.

The ECONADAPT project has also considered whether cost or benefit estimates from one study – such as the values from the studies in the inventory above - can be transferred to a new study. This would save considerable time and resources and is especially important for benefits as it is time and resource intensive to undertake primary benefit valuation studies. The project has found that such benefits transfer is difficult for adaptation, as there are numerous limitations including: data and methodological heterogeneity, temporal issues from primary studies, and thus there are likely to be errors associated with such transfer. The costs and benefits of adaptation depend on the method used, the objectives set, the types of adaptation considered, whether uncertainty is addressed, and whether policy implementation costs are included, as well as with the scenario, climate model and time-scale chosen. This cautions against the production of simple inventories or look-up tables on the costs and/or benefits of adaptation. What is possible, however, is to use existing studies to

help inform analysis by noting what methods are used and how robust their results are, and these are found in the ECONADAPT library and tool box.

Establishing principles of policy-led analytical framework

Historically, the main framework for assessing adaptation options has been centred on an impact-assessment methodology which takes a stylised "predict-then-optimise" approach. This raises some problems: studies tend to focus on the longer term and ignore uncertainty, and on their own do not provide relevant policy information for early practical implementation.

The ECONADAPT project addressed these limitations by developed a policy-led framework. This ensures that the policy context for adaptation – in the context of broader objectives and non-climatic factors – is understood first. It is also focused on near-term adaptation implementation, i.e. for decisions to be made in the next five years or so, using economic principles to identify options that are early priorities.

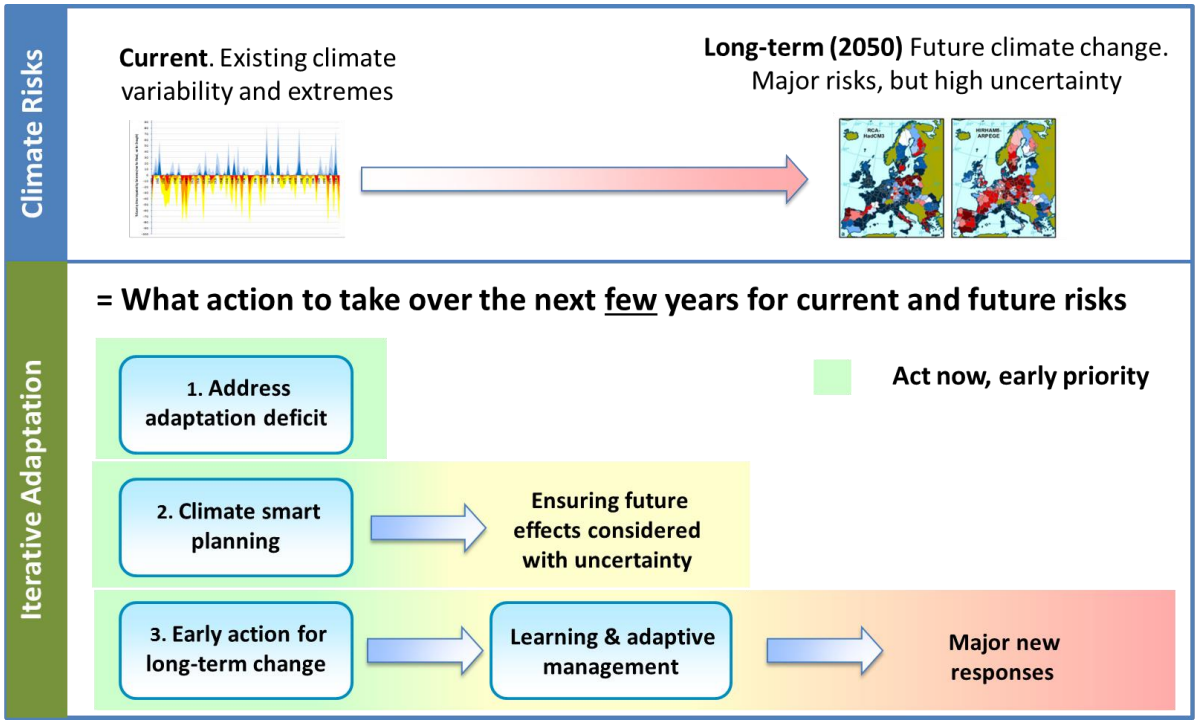
Finally the framework uses an iterative risk management approach and identifies three types of early adaptation investments that are priorities for early adaptation, illustrated in the figure, below:

1. Immediate actions that address the current risks of weather and climate extremes (the adaptation deficit) and build resilience to future climate change. This includes early capacity-building (non-technical adaptation) and the introduction of low- and no-regret actions, which provide immediate economic benefits as well as future benefits under a changing climate.

2. The integration of adaptation into immediate decisions or activities with long life-times, such as infrastructure or planning (climate smart development). This involves different options (to above) because of future climate change uncertainty. It involves a greater focus on climate risk screening and the identification of flexible or robust options that perform well under uncertainty.

3. Early monitoring, research and learning to start planning for the future impacts of climate change. This includes a focus on adaptive management, the value of information and future option values and learning so that appropriate decisions can be brought forward or delayed as the evidence and knowledges emerges.

The three categories can be considered together in an integrated adaptation strategy, often termed a portfolio or adaptation pathway. At the national or programme level, a portfolio of all three will be relevant, and they are particularly useful with respect to mainstreaming, i.e. the integration of adaptation into existing policies and plans. An important aspect is that the different types above require different methods, and thus different economic appraisal techniques.



The costs and benefits of adaptation

Integration of Socio-economic and climate data products

The final task of WP1 was to provide climate and socio-economic data projections of relevance for the case studies. In the context of ECONADAPT, this has been undertaken through a new focus on climate services, providing specific climate information and interpretation on climate change for each of the case studies, rather than providing a single common set of harmonised climate data: the focus is therefore on understanding the policy needs (and questions) and then deriving relevant climate data from CMIP5 and EURO-CORDEX to help answer these. To assist this, there was strong communication between the WP1 team and the case study WP leaders and partners.

In relation to climate scenario data, availability of data from the ISIMIP – the Impact Model Inter-comparison Project - facilitated data provision for impact estimation within ECONADAPT. Yet, the needs of the adaptation community are specific: when discussing adaptation measures, there is a much greater focus on the current climate and also on capturing uncertainty of future climate projections: the latter includes a move beyond multi-model ensembles to include more comprehensive scenario and climate uncertainty (including deep uncertainty) as well as specific metrics to allow the application of decision making under uncertainty methods. Finally, key to successful adaptation is often in understanding the extreme, low-probability, high impact events, i.e. the "tails of the distribution" rather than global mean temperature. We therefore recommend to devote more effort to examining the enormous amount of climate change models and data available through the lens of the adaptation community's needs and aims.

Socio-economic scenario development has been relatively limited within ECONADAPT, and mostly through the use of the SSP database. The RCPs and climate scenarios (and related climate change impacts) have been dominant in the selection of socio-economic scenarios, serving mostly as model input. As such, a similar conclusion as for the climate scenarios seems valid: the influence of the climate change impact community on the choice for socio-economic scenarios is very large, while the needs of the adaptation community may be rather different.

The choice for socio-economic scenarios is almost entirely dominated by the emissions that are generated by the scenarios. Although other aspects are described in the (global) SSP narratives, they are not used when discussing adaptation options. The potential of the framework of the SSPs with its scenarios that are constructed around the challenges to mitigation and adaptation are underused. For example, SSP1 should be seen as a scenario with high potential for adaptation and could thus be compared with SSP3 with its high challenges for adaption. Thus, we recommend the selection of scenarios based on the (differentiating) role they could play in the discussions on adaptation and mitigation policies, rather than based on their emissions.

WP2. Micro-economic foundations of adaptation assessment

Work Package 2 Objectives

The Work Package 2 objectives are:

- To elaborate methods to identify the opportunity costs of adaptation in relation to development and GHG mitigation objectives.
- To examine public acceptability and preferences for policy options and individual adaptation actions.
- To develop and test methods to quantify key parameters required for the economic assessment of adaptation given uncertainties in future climate and socio-economics.
- To develop and test methods to incorporate distributional objectives and non-monetary metrics in the economic assessment of adaptation.

Whilst this Workpackage undertook a wide range of activities, a selection of these are highlighted here.

Defining the opportunity costs of adaptation: Evaluating investment in sector-specific adaptation relative to system-wide adaptation.

Adaptation actions target climate drivers, by attempting to reduce vulnerability to climate risks and acting on climatic opportunities. The two categories of adaptation actions, sector-specific and system-wide, achieve these goals by different means; sector-specific actions directly target climate drivers, whereas system-wide actions indirectly target climate drivers. We developed an analytical framework that provides a process that decision makers can follow in order to make reliable comparisons between these types of adaptation actions. It is hoped that this process will improve the representation of system-wide actions in the adaptation discourse.

The framework formally distinguishes between system-wide and sector-specific actions to clarify the differences between them. This formal distinction also helps explain the

process for evaluating system-wide actions; the indirect benefits associated with system-wide actions can be determined by assessing how they change adaptive capacity. The framework suggests that the value of adaptation actions facilitated by a system-wide action (through build adaptive capacity) should be indirectly attributed to it. These are the indirect benefits of system-wide actions that the framework helps identify. This is particularly relevant for economic appraisals of adaptation actions, where the full benefits and costs associated with an action need to be evaluated before deciding between alternatives in order to avoid a misallocation of resources. Therefore, the framework plays an essential part in helping decision makers avoid maladaptation, by ensuring they can reliably compare system-wide actions with alternative adaptation actions.

In addition, the framework accounts for the problem of additionality for both system-wide and sector-specific actions. By categorising the benefits and costs of adaptation actions into groups relating to both climate and non-climate drivers, decision makers can identify how different objectives are targeted by adaptation actions. This is particularly important for system-wide actions, which are likely to target non-climate objectives more than sector-specific actions. It is also relevant for overseas development assistance, where sustainable development, mitigation and adaptation are often seen as separable issues for the purpose of funding. However, the framework helps clarify that adaptation actions may have co-benefits (and co-costs) relating to objectives other than adaptation. Again, this will help decision maker identify the full benefits and costs associated with adaptation actions, and allow them to make more reliable comparisons between the alternatives.

Preference-based evaluation of trade-offs between different forms of adaptation.
The objective of this task was to enhance methods for examination of preferences both for public adaptation programmes and for individual adaptation actions. Climate change is expected to impact the water system in many countries, leading to more extreme weather patterns, causing for example higher likelihoods of flooding, drought and heat waves and also increasing the severity of such occurrences. The research examined preferences of citizens of three European countries, the Czech Republic, Italy and the United Kingdom, for adaptation plans and measures to limit damages from floods and droughts. For this purpose, the researchers conducted a questionnaire survey in the three European countries. The key findings were:

- Willingness to pay for additional flood and drought adaptation measures as increased monthly bill for water consumption paid by a household ranges from €15 to €19 in the Czech Republic, from €35 to €45 in Italy, and from €33 to €44 in the UK (using market exchange rate).

- In all three countries, citizens prefer reducing the severity of climate change impacts as opposed to reducing the number of affected people in the population.

- British citizens prefer adaptation programs that reduce the impacts of floods; whereas Czech citizens consider reducing the impacts of droughts a more important objective.

- Rainwater harvesting is the most popular measure in all three countries. In the United Kingdom, large reservoirs and dams come second in preference; large dams being the least popular measure among Czech citizens.

- Citizens in all three countries express relatively high preference for two nature-based adaptation measures: creating wetlands and changing the use of agriculture land.

The results give a first indication that policy makers from the UK, Italy and the Czech Republic can increase public support for their adaptation plans and measures by following the preferences described in this research. Policy makers from other countries may choose to use this information as a starting point for a separate inquiry at the local, regional or national level.

WP3 Scaling, Aggregation and Transfer

Work Package 3 Objectives

WP3 has been defined to answer to three main objectives:

1. Ensure consistency and comparability in estimates at different scales for different sectors and different time periods.
2. Develop protocols for transferring data from the micro scale to the macro, and vice-versa.
3. Address systemic change and evaluate the right adaptation policies and measures for dealing with it.

The aim of the first task was to provide protocols to link data on costs and benefits of adaptation at different scales. A literature review was therefore performed to identify the costs and benefits of adaptation at the micro scale in order to develop guidelines to transfer this data to other places without such data. The following sectors were analysed: agriculture, coastal zones, ecosystems, energy, extreme events, health, infrastructure and water. the guidelines for data transfer. The key findings are reported above in association with the cost and benefit database

The literature on adaptation cost and effectiveness is still sparse. The biggest challenge with adaptation relates to its highly site/case-specific nature, which makes it very difficult to produce meaningful aggregated measures on either adaptation costs or effectiveness using uncontroversial aggregation criteria. However, some aggregation of adaptation costs and effectiveness is necessary when this "family" of measures has to be evaluated in a more strategic perspective, for instance comparing its relative convenience and viability against other actions to cope with climate change (e.g. mitigation), or, more in general, against other alternative uses of public and private funds. We have reviewed the existing literature on costs and benefits of adaptation to verify if the information available would allow building adaptation functions into the CGE model used within the ECONADAPT project. Results of this scrutiny show that, at best, cost-effectiveness ratios for adaptation in different areas, and in just a subset of countries, can be determined. This information is however highly insufficient to allow the implementation of adaptation functions into a CGE model. Accordingly, the calibration of adaptation in the ICES model will be based on a completely different approach; rather than trying a highly controversial if not unappropriated extrapolation

and generalization from the literature. However, we do also outline an in-depth methodology that could – in principle - be used to model adaptation against sea-level rise, and describe the methodology required to implement adaptation in dynamic optimization models.

We investigate the problem of systemic risk in the context of climate change, reviewing the extent to which this concept is captured in existing tools used in the economic analysis of climate change and suggesting improvements to these tools. The analysis and suggestions from the deliverable are illustrated in an application examining the Syrian refugee crisis as an example of climate-induced migration. Systemic risk is defined as a potential damage with repercussions that transcend national borders or require transformational adaptation. Economic literature has concentrated on market costs and to a lesser extent non-market costs, but costs stemming from systemic change, particularly those impacted by socially contingent responses to shocks, remain untreated. We review methods for addressing these latter categories of costs.

We present an evaluation of commonly used economic tools in the context of systemic risk. Cost-benefit analyses are reviewed and questions around the accuracy of predicting non-market costs are presented. Methods for calculating the Social Costs of Carbon are detailed, with critiques of existing practices drawn from the literature. Integrated Assessment Model shortfalls are presented, as well as the socioeconomic pathways used in IPCC projections. Theoretical criticisms of the treatment of systemic risk are discussed, including Weitzman's Dismal Theorem and alternative applications of discount rates based on risk and timeframe. Findings of the Stern Review on the Economics of Climate Change are presented, with specific attention to the amplification of damages in models when catastrophic climate change is considered. We suggest strategies responsive to the issues identified, including recursive modelling in cost-benefit analyses that is responsive to developments in climate information. Ranged estimates for social costs of carbon are presented as one method

In an application section, the suggestions are contextualised for the ongoing refugee crisis stemming from Syria. General background on the economics of migration and the connection between climate change and human migration are reviewed and details of the Syrian crisis are summarised. Scientists have shown a connection between extreme drought conditions and conflict in the region. Costs stemming from migration, including those to both migrants and destination countries, as well as non-market costs that are difficult to quantify. Available information on the volume of migrant flows to various countries and the refugee-related expenditures are presented to provide a snapshot of the costs of a systemic event related to climate change. Strategies presented earlier in the paper are presented in the context of the migration scenario, model improvements, scenario pathway analysis and maxi-min policies are all presented as analytical approaches to manage similar risks over the future.

WP4 Treatment of Uncertainty in Economic Assessment of Adaptation

Work Package 4 Objectives

WP4 is concerned with cascading uncertainties connected with climate change pathway and uncertainties resulting from the assessment of economic costs and benefits of

adaptation especially in mid- to long-term perspective. The overall main objective of WP4 is to:

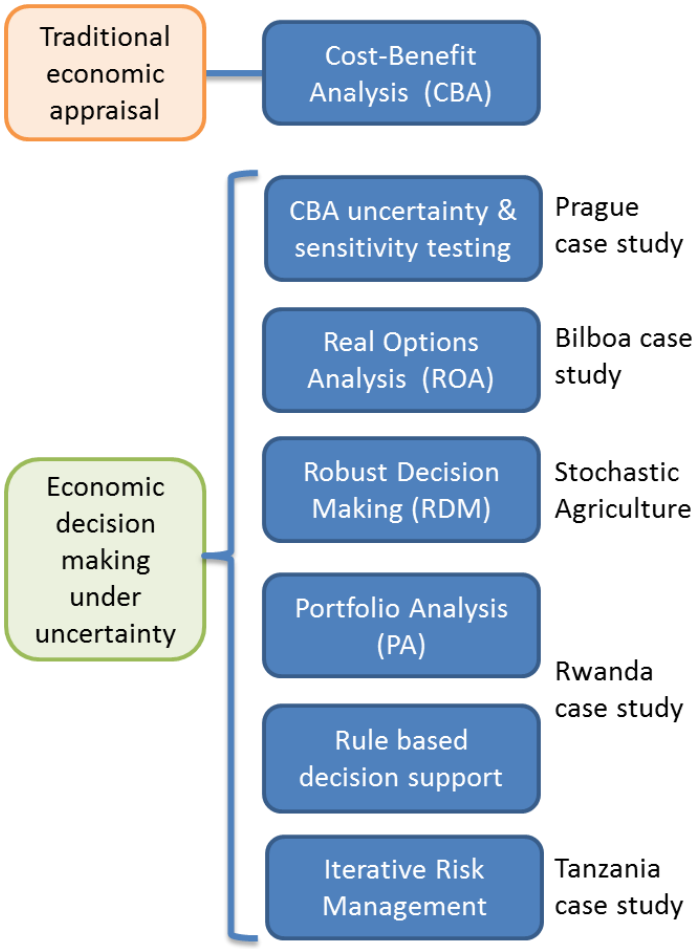
- Explore how the relevant uncertainties can be incorporated into existing decision-support tools that rely on economic data, and how such tools should best be modified or improved to better accommodate uncertainty.

We first review the most critical aspects relevant to a very broad field of uncertainty as it relates to climate change and adaptation to climate change. We presented and compared with each other the different views and problem structuring approaches. Starting from general definitions of uncertainty and risk and going through their classification at a rather universal level of understanding (intentionally not employing mathematical constructions) we moved to climate change specific applications of those. We especially highlighted the concept of clustering present uncertainties into climate-, socio-economic-, and policy- relevant ones. All those are playing important roles for long term adaptation, but not necessary in the short term. We provide examples of existing uncertainties based on recent scientific studies in several sectors and highlighted the importance of integrated cross-sectorial analysis especially in the presence of systemic risk. Another equally important concept is the strategic and operational planning of adaptation, which is emphasized in this document.

We then provide an overview of state-of-the-art methods for decision-making under uncertainty and risks. While discussing particular approaches, we highlight the importance of integrated (cross-sectorial) analysis. Other aspects we suggest for consideration within the adaptation context include: complex multivariate analytically intractable risk distributions, long horizons of evaluations, strategic and operational planning and management of risks.

We carry out an analysis of the methods specifically focusing on their applicability – their strengths and weaknesses within an adaptation context. To overcome critical deficiencies found, we suggested a range of improvements/new methods and illustrated those with a few appropriate examples stemming from current/previous research that is close to (but not necessarily the same as) the topic of the ECONADAPT project.

The ECONADAPT project has focused on quantitative methods, given their role in the economic appraisal of adaptation. The project has reviewed and tested different decision support methods, and has produced guidance on their applicability and use (http://econadapt-toolbox.eu/methods). This has included a focus on decision making under uncertainty methods, recognising this is as a key issue for adaptation. Figure 1 shows how a range of case studies has been used to illustrate these different decision-support tools.



The project has produced guidance on which methods of economic appraisal might be applicable for different adaptation problems, and undertaken case study applications on real options analysis, portfolio analysis and iterative risk management in a range of sectors and countries. These are summarised in the case studies, outlined below. These provide valuable information on the state-of-the-art capacity in assessment of adaptation options that consider treatment of uncertainty. The work carried out in the case study work packages demonstrated also the progress beyond the state-of-the-art and led to several important implications. In summary, the findings from the case studies and recommendations supported by those can be summarized in the following bullet points:

1) Uncertainties in climate change and socio-economic projections do play an important role in the analysis of adaptations an cannot be ignored (e.g. projected shifts in tea and coffee altitude suitability bands as in Rwanda WP9, projected changes in crop yields and agricultural production as in WP7, projected sea level rise as in Bilbao WP6). There are, however, cases where there is an urgent need for change due to already observed climatic changes (e.g. seaweed farming in Zanzibar WP9).

2) The specific type of uncertainty – epistemic – and its influence on the assessment results drives the need to close knowledge gaps. Therefore, an effort is required to create and gather new knowledge. All the case-studies were able to unveil and demonstrate these gaps, e.g. inclusion into the modeling of

structural protection measures that are part of national flood protection plans (WP5), long term hydrological modeling (WP6 Bilbao and Vltava), depth-damage functions (WP6 Vltava), spatially-detailed land cover (WP7), agricultural crops production (WP8 Autonomous adaptation), water price and cost of irrigation (WP8 Planned adaptation), climate induced changes in pest and disease modeling (WP9 Rwanda), quantification of the frequency of future extreme events (WP9 Zanzibar).

3) There is a strong need for monitoring and data collection, because data limitations frequently play a critical role in adaptation assessments as demonstrated by the project's case studies. The data are needed to support research and creation of knowledge. Even though in many cases a long enough time series data might be needed to better calibrate respective impact models (e.g. a cultivar parametrization potentially useful for crop yield assessments), in some cases a one-time consistent picture could help fill the gap (e.g. a spatially-detailed land cover in WP7).

4) At the science – policy interface, there is a need to communicate the findings of analyses that include a wide representation of uncertainties and therefore provide more sophisticated information than assessments carried out before, e.g. probabilistic formulation of disaster risk reduction investments benefits as a reduced possibility of disaster fund depletion in WP5, results of the real options approach in WP6 Bilbao, robust recommendations derived from an application of the stochastic GLOBIOM model in WP7. There is a need in common language and common understanding of modelled/estimated processes.

5) There is a need to implement and carry out further real-life testing of new approaches. This is where the practice could prove and also correct and improve the methodology.

6) Specifically, a key finding of the project is the need for 'light-touch' approaches of these methods, in recognition that they are technically complex to apply and require considerable time and resources: these would capture the conceptual aspects of these uncertainty approaches, while maintaining a degree of economic rigour.

WP 5: Case Study Disaster Risk Management

Work Package 5 Objectives

The objectives of workpackage 5 are to:

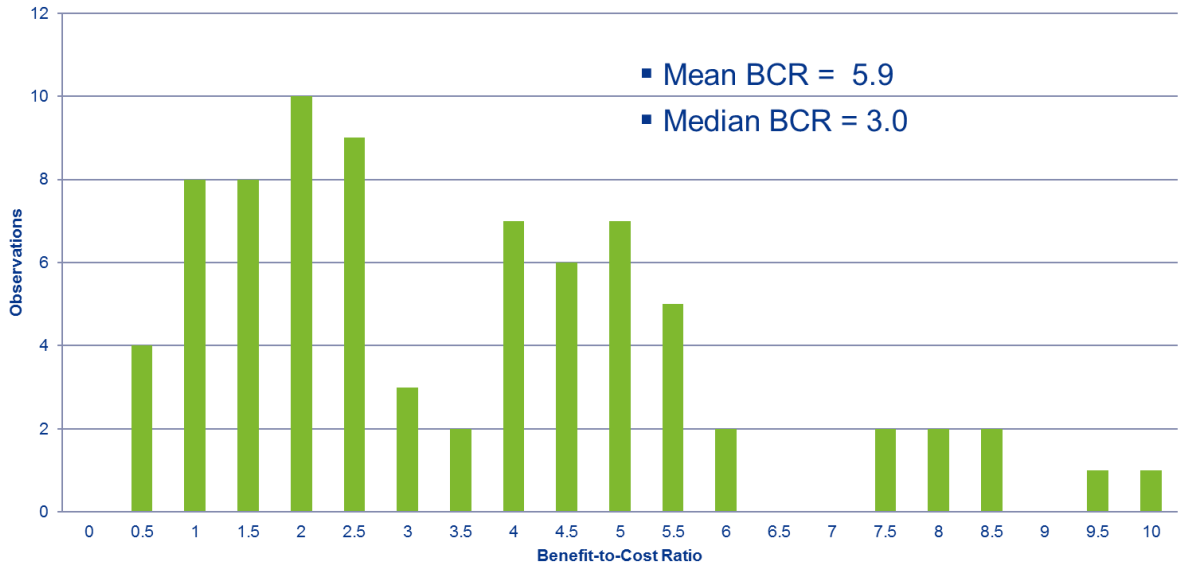
- Develop an improved protocol for comparative economic analysis of options for adapting and improving disaster risk management (DRM) to near future changes in extreme weather events.
- Identify the potential scale of public finance resource commitments for improved DRM under climate change in the EU.
- Develop rules for transferability of the case study results to general guidance for

the economic assessment of adaptation.

Natural disasters (from current climate variability) already lead to high economic costs in Europe, including from major floods. Climate change is likely to increase the frequency of these extreme events, even in the short-medium term. As these will be amongst the highest near-term economic costs of climate change, managing these risks is an early priority for adaptation.

The ECONADAPT project first compiled an inventory on the economic benefits of flood protection investments in Europe. The inventory found 110 observations from 32 studies in 17 countries. An analysis of the studies demonstrates that current adaptation to disasters has high benefit to cost ratios (BCRs), with a median value of 3:1. Analysis of different types of measures found the highest BCRs were for investing in preparedness, rather than prevention or amelioration.

The study also undertook case studies on the use of decision-making tools in flood risk management in four countries (UK, the Netherlands, the Czech Republic and Austria): interestingly, this found that the countries use different methods for appraisal of flood investments, highlighting the need to consider these aspects in harmonising future adaptation expenditures across Europe.



Benefit to Cost ratios for Flood Protection Investments in Europe.

The ECONADAPT project also complemented this more bottom-up analysis with a top-down analysis, looking at the fiscal consequences of climate change exacerbating current national level disasters in relation to national budgets. A case study was undertaken using economic and fiscal modelling to look at contingent disaster liabilities.

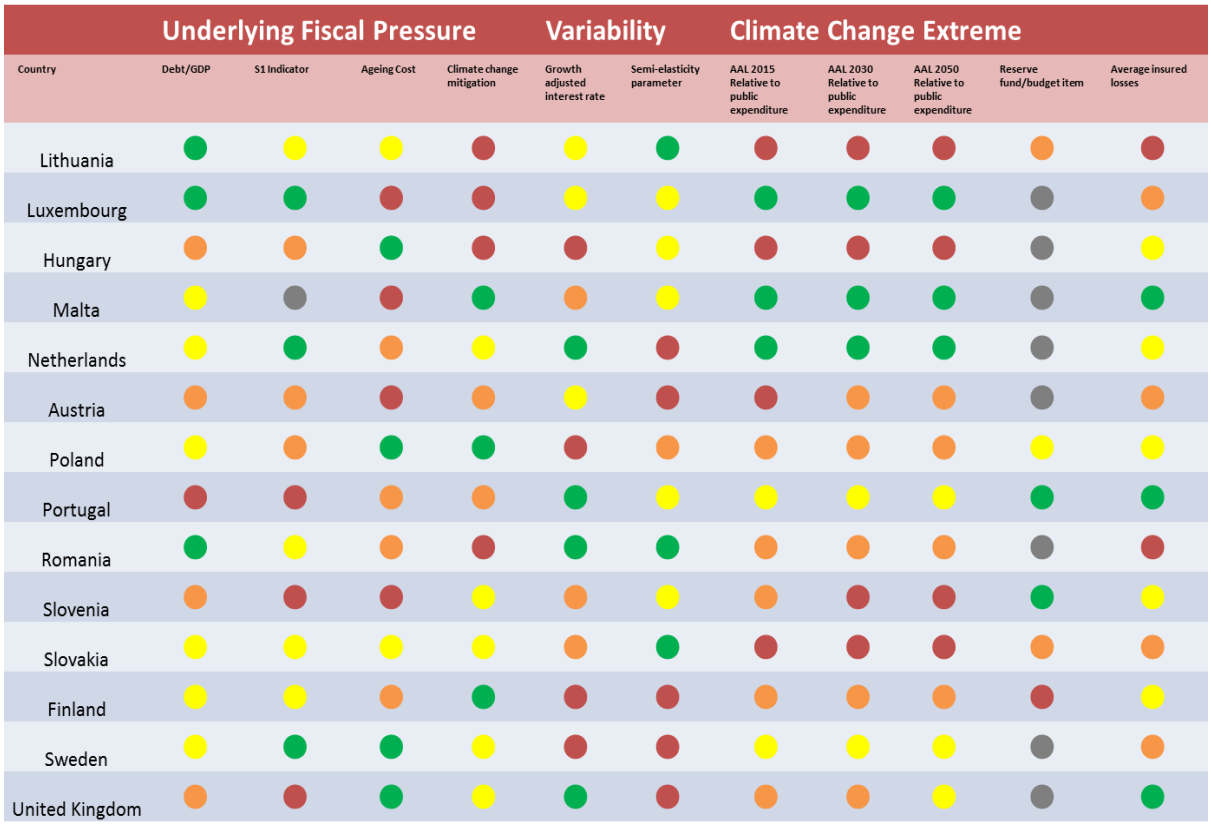
The case study modelled the potential liabilities using a stochastic assessment of debt at the national level with a case study in Austria. This included the analysis of explicit liabilities, for example, the rebuilding of damaged public infrastructure, but also implicit liabilities, such as support to the private sector and households to cover

estimated losses. The results show that the fiscal costs of increasing climate extreme events could be a very significant public finance issue.

Based on this work, a fiscal scorecard has been produced for all EU member states. This gives an overview of inter-related issues in relation to longer-term fiscal drivers and sustainability, covering climate and non-climate drivers. The analysis shows there are large economic risks from climate extremes - relative to the size of economic and public finance resources - in Hungary, Slovenia Latvia, Lithuania and Slovakia. This analysis highlights that these countries may need fiscal consolidation in the medium to long-term and that proactive fiscal risk management is likely to be important.

EU Fiscal Scorecards. Source ECONADAPT.

	Underlying Fiscal Pressure				Variability		Climate Change Extreme				
Country	Debt/GDP	S1 Indicator	Ageing Cost	Climate change mitigation	Growth adjusted interest rate	Semi-elasticity parameter	AAL 2015 Relative to public expenditure	AAL 2030 Relative to public expenditure	AAL 2050 Relative to public expenditure	Reserve fund/budget item	Average insured losses
Belgium	🔴	🔴	🔴	🟠	🟠	🔴	🟠	🟠	🟠	🟠	🟢
Bulgaria	🟢	🟠	🟡	🟢	🟠	🟢	🟠	🟠	🟠	🟠	🔴
Czech Republic	🟢	🟡	🟠	🔴	🔴	🟢	🔴	🔴	🔴	🔴	🟢
Denmark	🟡	🟢	🟢	🟡	🟡	🔴	🟡	🟡	🟡	⚫	🟢
Germany	🟠	🟢	🔴	🟢	🟢	🟠	🟢	🟢	🟡	⚫	🟠
Estonia	🟢	🟢	🟢	🟢	🟡	🟡	🔴	🔴	🔴	🟠	🔴
Ireland	🔴	🔴	🔴	🔴	🟢	🟠	🟠	🟠	🟡	⚫	🟢
Greece	🔴	🟡	🟡	🟢	🔴	🟡	🟡	🟡	🟡	⚫	🔴
Spain	🔴	🔴	🟠	🟠	🟠	🟠	🟢	🟢	🟢	⚫	🟠
France	🔴	🔴	🟡	🟠	🟢	🔴	🟡	🟡	🟡	⚫	🟢
Croatia	🟠	🔴	🟢	⚫	🟠	🟡	🟢	🟢	🟢	⚫	🔴
Italy	🔴	🟠	🟠	🟡	🟡	🟠	🟡	🟡	🟡	⚫	🟡
Cyprus	🔴	⚫	🟢	🟠	🟠	🟠	⚫	⚫	⚫	⚫	🟠
Latvia	🟢	🟡	🟡	🔴	🟡	🟢	🔴	🔴	🔴	🟠	🔴



WP6. Case Study: Economic Project Appraisal

Work Package 6 Objectives

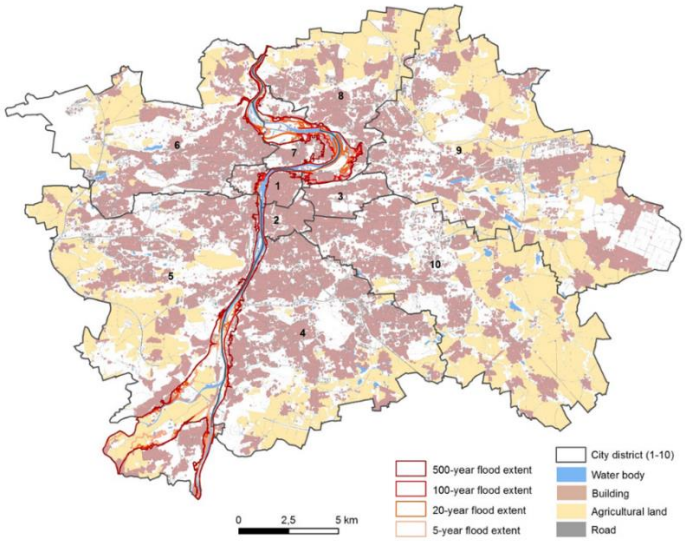
The principal objective of WP 6 is:

• Through rough close engagement of stakeholders and policy organisations, to assess adaptation costs and their uncertainties that are associated with large capital investments in infrastructure in 2 case studies.

The case study focus was to explore the consideration of adaptation into economic project appraisal. This is a priority for large infrastructure projects (including European Structural and Investment Funds), because of their long life-times and high exposure to future climate change. It suggests the incorporation of climate risks into existing planned investments as well as the need to develop investments designed specifically to address climate change. The project undertook two real-world case studies that engaged policy makers and applied alternative decision-support methods to project appraisal.

The first case study was focused on flood risks in the city of Prague, which has been heavily impacted by floods in recent years. The study looked at an ex-post appraisal of adaptation using a cost-benefit analysis considering a full range of social costs and benefits, including environmental effects. The study used a suite of hydrological and damage models, considered future shared socio-economic pathways and detailed climate model projections, and included treatment of uncertainty through alternative means. It undertook a detailed analysis of flood return periods and expected (annual)

damages – now and under future scenarios – and estimated the economic costs and benefits of adaptation.



The study used sensitivity analysis to undertake a detailed analysis of uncertainty, considering how different attributes/factors affected the CBA results, and thus assessed the robustness of the investment under varying conditions.

The second case study focused on a new urban development in Zorrotzaurre, Bilbao, looking at adaptation options to reduce coastal and river flooding by opening a canal on the Deusto channel to convert the area from a peninsula into an island.

The analysis used a Real Option Analysis to appraise this potential investment in flood reduction. It used detailed climate model projections and hydrological modelling, assessing the full economic costs of climate change (including on cultural heritage, human health and indirect second order effects). It then applied the real options framework to investigate whether to invest or wait in relation to the option, testing this with additional sensitivity analysis (for example around the discount rate).

The results of the two studies were used to investigate what key factors had most effect on the results, using the results of the sensitivity analysis. This found the climate model and socio-economic uncertainty, along with the discount rate, were most important and therefore requiring most attention in uncertainty analysis. The lessons from the case studies – along with the earlier methodological development work – were used to produce guidance on project economic appraisal.

The guidelines are structured in 22 steps for the practitioner to follow, divided in the areas of: context analysis; hazard assessment; impact assessment; adaptation; economic assessment; and decision-making with consideration of stakeholders. Each step is explained in a small section of typically half to two pages, containing: a brief overview of the problem; a display of the methods available to tackle it; a brief account of what was done in the ECONADAPT case studies, and what can be learned from them; recommendations about good practices. In addition, we have compiled summary tables of the steps, aimed to provide: 1) an impression at a glance of all that needs to be accomplished in the adaptation appraisal; 2) a schematic map with the minimal amount of information that the practitioner should keep in mind at any moment.

Main finding 1: the appraisal, and wider evaluation and of the possible options for adaptation is by its own nature a comprehensive and multidisciplinary exercise. The practitioner should count on (access to) a range of expertise to carry out the exercise.

Main finding 2: it is possible to summarize the essential aspects of the appraisal in a set of steps that should be carefully considered and at least inspire the practice.

Future research could focus on the needs to tailor these guidelines in different contexts in Europe and elsewhere, to comply with the needs of local practitioners and circumstances. Especially, it would be very instructive to assess how frequently-adopted "light-touch" approaches to appraisals compare, in terms of their accurateness, to the more extensive practices recommended in our guidelines.

WP7 Case study: Policy Impact Assessment

Work Package 7 Objectives

The objectives of the WP are to identify possible adaptation options in a reformed CAP and assess their synergies, but also the trade-offs with other goals of the CAP, as well as formulate some advice for improved Policy Impact Assessment guidelines.

Policy analysis involves applications at the European or National Level, whether this is for major sector policy or National Adaptation Strategies. As with project appraisal, the existing tools for policy impact assessment do not allow consideration of the major challenges from adaptation, and there is a need to move beyond the current state-of-the-art. The study within ECONADAPT study looks to advance adaptation in policy appraisal. As a test of the methodological issues involved in moving adaptation into policy impact assessment, we undertake a case study on agriculture and the Common Agricultural Policy (CAP). Adaptation interventions are especially relevant for policies that involve the flow of substantial EC funds, particularly as many such areas will be affected by climate change. Furthermore, a key finding from emerging adaptation requires cross-sectoral responses to be most effective, rather than narrow sectoral analysis. These linkages are recognised in our modelling.

To assess the current policy context, we undertook a a review of the EU CAP reform - based on a literature study and stakeholder consultation - that scopes out the problems and needs that decision-makers are faced with when developing adaptation policies in

the context of the CAP reform in order the make the European agricultural sectors more climate resilient. Key findings include the following:

1. Although the current CAP already has several mechanisms to enhance adaptation and to pay more attention to sustainability and climate resilience, further strengthening of these mechanisms should be considered, informed by more substantial monitoring systems.
2. The set of options for mainstreaming climate adaption in the CAP ranges from simple provision of information on climate change and adaptation options in the context of the CAP policies, at one extreme, to a fundamental revision of the CAP mechanisms, at the other extreme. This leads to much larger shares of the CAP payments that are directly related to environmental targets and investments in adaptation.

A priority area in this case study was to finalise the representation of the climate-yield functions relavent to the modelling exercise. To this end, we reviewed the literature on the impacts of climate change on agricultural yields that have been modelled using crop models, and used as an input into economic models. The modeling set-ups in the studies reviewed are substantially different, the differences including: basic setups (time horizon, spatial resolution, regional setup, sectoral resolution for general equilibrium models); different reported variables, different definitions of these variables (e.g. prices), different baselines; choice of socio-economic scenarios; derivation of biophysical crop yield changes; inclusion of global trade relations and inter-regionally consistent climate change effects on crop yields, and; adaptation assumptions. The papers in the assessment found that while aggregate effects are relatively small, this masks large regional differences, in particular, more positive effects in Northern and negative effects in Southern Europe are found. Furthermore, effects in the agricultural sector are large compared to other sectors for Northern and Southern Europe. However, the inclusion of international trade effects - as well as explicitly excluding or including adaptation - is decisive for results and can potentially reverse signs.

In terms of recommendations for generating a consolidated and comprehensive picture of climate change effects on agriculture in Europe, the following were given: transparent and efficient communication between scientists and stakeholders on uncertainties; the need for a structured assessment of agro-economic impacts of climate change in Europe based on a suit of climate, crop and economic models, and including related sectors like water and energy; the agricultural products (crop types, grasslands, livestock) included in these studies needs to be extended, as well as the occurrence of weeds, pests and diseases; the need to include global trade effects, consistent climate change effects and adaptation in all regions, and; the policy relevance of the studies needs to be ensured, through close interaction with stakeholders, e.g. in the design phase of studies.

Stochastic GLOBIOM is applied for the analysis of different CAP measures intended to support EU farmers in dealing with climate change and production risks. In

Ermolieva et al. (2016) the model is applied to the case of increased food storage facilities, which can be viewed as catastrophe pools to buffer production shortfalls and fulfill regional and global Food-Energy-Water-Environment Security requirements when extreme events occur. The effects of storage capacities on expected shortfalls was measured using the Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) risk measures. Our analysis focuses on both biophysical and economic processes, but it is still partial as it simulates only the agricultural and forestry sectors. However, GLOBIOM can be efficiently linked with other sectoral models.

Although not exhaustive, reversible "low regret" adaptation measures are modelled that are short-term and address current climate variability, such as different direct payment measures, and autonomous adaptation of switching to less impacted and more profitable crops. More structural, long-term measures relate to the construction of irrigation schemes or storage facilities. All these measures can be part of the CAP, meaning that estimating their costs and benefits are an important part of the policy appraisal and do not require additional public expenditures.

Results show that the robust recommendations of the stochastic model, compared with a deterministic model, can save a considerable amount of maladaptation and sunk costs. Using a deterministic model, an extreme shock may lead to a large uptake in cropland, which may imply large irreversible costs. By taking into account years with good and bad yields, the stochastic model provides a middle way in terms of uptake of cropland between an average yield deterministic model and an extreme shock deterministic model. Furthermore, differences between alternative direct payment schemes are generally small, as is consistent with the literature. Under all direct payment schemes more land is allocated to cropland, managed forest, and natural land, and less land to primary forest and grassland compared with a situation without direct payments. There is a strong synergy between financial and structural measures. The introduction of direct payments is therefore analyzed together with the introduction of storage facilities. The introduction of both direct payments and storage facilities decrease water demand and save investments into irrigation expansion, implying a substitution effect between policy measures.

Complementing this, a survey was undertaken in Greece looking at farmers' perceived risks and attitudes to climate change adaptation, as well as their preparedness and capacity to adapt and future actions. It identified additional adaptation options at the farm level, and the WTP for these, noting that private adaptation is unlikely to be optimal alone because of various market failures.

Recognizing that a well-performed policy appraisal is a key part of good policy making, the EC provides Policy Impact Assessment Guidelines (PIA) for preparing policy proposals (European Commission, 2009). Our findings have implications for these guidelines in four principal areas; these are:

1. The EC Policy Impact Assessment Guidelines (PIA) for preparing policy proposals, (European Commission, 2009), suggest that risk assessment is based on only one baseline scenario (defined in section 5.3 of the document). However, with a longer term perspective that adaptation requires, problems can occur when a different scenario than projected materializes. We therefore suggest that the entire appraisal and specifically the risk assessment should be carried out based on at least three scenarios, perhaps using the IPCC Shared Socioeconomic Pathways (SSPs).

2. In section 9 of the PIA guidance document, three ways in which the different options can be appraised are described. These are cost-benefit analysis, cost-effectiveness analysis, and multi-criteria analysis. None of these include a rigorous assessment of policies under uncertainty. We, therefore, suggest combining risk assessment with these three appraisal tools by, for example, integrating into this text descriptions of other appraisal tools, such as ROA, Portfolio Analysis (PA) and Robust Decision Making (RDM) that are already being used in the project appraisal of adaptation options. The stochastic IAM we use in the agricultural policy context incorporates a number of the principles incorporated in these tools and could also be promoted in this regard.

3. Given the very detailed and comprehensive list in tables 1-3 of the PIA guidance, on economic, social and environmental impacts, all relevant sectors of society appear to be covered. But as conventional tools may fall short of being able to incorporate the effect of a policy on different sectors, it may again be worthwhile to refer to the possibility of using, e.g. stochastic IAMs to integrate a multi-sector assessment where competing objectives need to be made explicit. We therefore suggest that developing and using such models may be helpful for the appraisal of other complex policies in the face of climate change.

4. Although private actors, farmers in the agricultural sector clearly have responsibility for adaptation to climate change, many farmers have imperfect information on climate change impacts and the adaptation options that are available and suitable. This implies that it is important to consider whether the financial means incorporated in current CAP arrangements can be used to provide stronger incentives to farmers to adapt to climate change and therefore to make the agricultural sectors in Europe more climate resilient and less greenhouse gas intensive

WP8: Case study: Macro-economic effects of adaptation

Work Package 8 Objectives

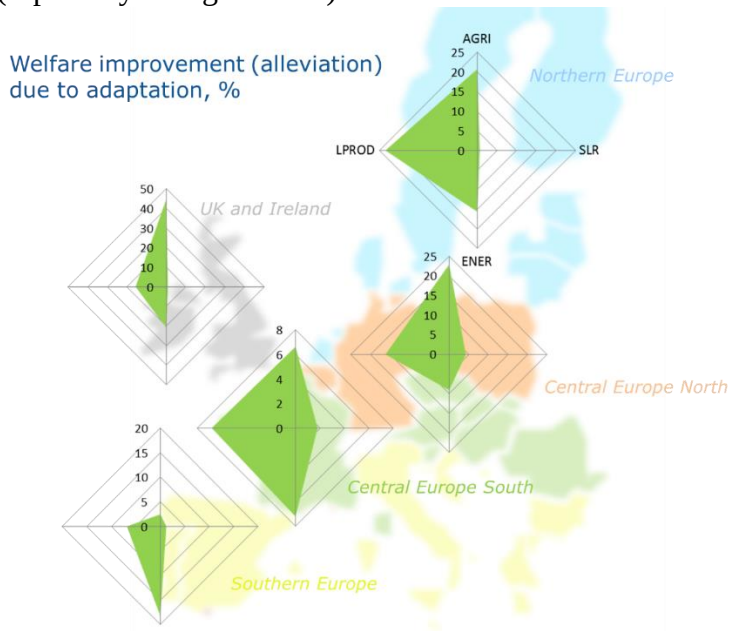
The objective of WP8 is to assess the macro-economic implications in terms of GDP, sectoral activity and household welfare of: i) autonomous, and ii) planned adaptation for EU countries.

There is an increasing interest in the macro-economic effects of adaptation, i.e. the economy-wide effects. The ECONADAPT project has assessed these effects using computable general equilibrium (CGE) models. The project has looked at market-

driven (also known as autonomous) adaptation which involves demand and supply reactions to changes in relative prices. It has also extended these models to look at planned adaptation.

The market driven adaptation was assessed with a global multi-country, multi-sector CGE model (CAGE-GEME3). The analysis assessed how market driven adaptation to climate change could reduce potential climate change damages. It considered three key responses: labour mobility, both across sectors and region;, the degree of substitutability between capital and labour in the production function and the degree of substitutability for trade flows and domestic production. At the global level, the study found that market based adaptation reduced climate change damages by approximately a third (compared to a case without adaptation) for both GDP and welfare losses.

The analysis also focused down to Europe, and investigated the effects by region. Within the EU, the welfare-enhancement effect of adaptation is smaller at lower latitudes. The greatest benefits are in the UK & Ireland, followed by Northern Europe and the Central Europe North regions – shown in the figure below for land productivity (LPROD), agriculture (AGRI), sea-level rise (SLR) and energy (ENER). These differences reflect the initial size of impacts but also the potential for substitution (especially for agriculture).



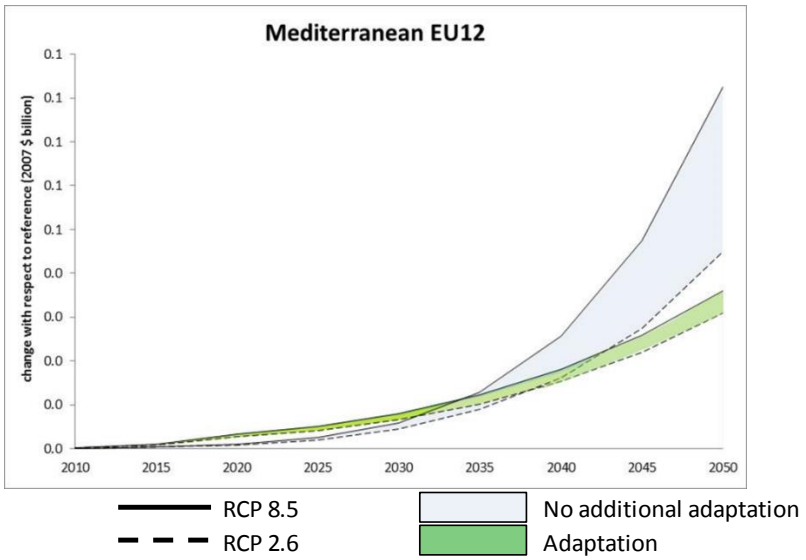
EU Welfare improvements from autonomous adaptation (sector and region)

The analysis of planned public adaptation also used a CGE modelling analysis, undertaking two case studies - one on increased demand for irrigation to address agricultural impacts and another on public sector investment in coastal adaptation to sea level rise (SLR) – to consider the economy-wide implications of planned adaptation actions. The analyses have looked at how planned adaptation increases public expenditure, both on climate related public goods (such as information acquisition and dissemination on likely extreme events) and in protecting public and private assets at risk.

The agriculture case study looked at increased demand for irrigation services to reduce climate change impacts – extending an existing CGE model to consider land supply

structure/rents and conversion of rain-fed land, along with the additional costs that farmers face when they decide to expand irrigation. In the baseline (with climate change), lower latitude countries are most negatively affected either in terms of decreased crop production or lower GDP. Under the adaptation scenarios, irrigation expansion reduces the initial productivity losses and is considered an effective option (especially for lower latitude countries), enabling higher production and lower GDP losses, though converting rain-fed into irrigable land and expanding irrigation services is costly and increases agricultural prices which reduces demand expansion. However, the overall macro-economic effects (globally) are small, as agriculture is a low contributor to value-added and GDP, though international trade effects also influence this result, as regions with lower increases in domestic prices (compared to world prices) export more and vice versa. Climate change – and the planned adaptation response - will thus reallocate crop production from more to less affected sectors and countries, and from developed to developing countries, as the latter have relative advantages from lower irrigation costs. The sea level rise case study investigated coastal adaptation in a CGE model and considered the impact on public finances, by extending the model to consider government as a separate actor. Planned adaptation requires increased public expenditure. These measures are implemented locally, but often require large scale upfront investments and can induce additional indirect economy-wide effects through an increased demand for adaptation services and the reallocation of resources to produce them.

A no adaptation scenario was first considered, which showed high GDP losses in all regions. Public deficits also worsen as sea-level rise affects negatively land, capital and labour and ultimately GDP. The analysis then considered a planned adaptation scenario (with investment funded by issuing public debt). GDP gains are observed everywhere but especially in developing countries where sea-level rise impacts are higher and adaptation is particularly effectivePublic deficits are initially higher when adaptation investments are being put in place, but become lower only in the long run (see figure). This is a direct consequence of the long-run nature of sea-level rise. What is interesting is that adaptation expenditure can enable virtuous processes, and the positive effects on public finance sustainability can be positive, even though initially financed with debt.



Impacts on public deficit for Mediterranean EU12 in 2050 (with and without adaptation)

WP9. Case study: International Development Support

Work Package 9 Objectives

The objectives of this work package are to:

• Undertake a case study on the economics of adaptation in the context of international development support.

• Undertake this work on a real case study example aligned to developing country adaptation flows and analysis.

• Consider lessons learned and transferability of the case study to methods and guidance

One of the major flows of adaptation finance – consistent with international pledges - will be from Europe (EU and MS) to developing countries. There is a strong role for economic appraisal in helping to assess the effective use of these resources and the links to financing. While these involve project and policy appraisal, there are several key differences (to the EU) with the application of adaptation economics to developing countries. First, the impacts of current climate variability and extremes are much higher, and combined with the higher discount rate / interest rate, this means a greater focus on the short-term. Second, data availability and capacity are much lower, making quantitative analysis more challenging. There also tends to be a greater focus on non-market and informal sectors, and the issue of equity (especially amongst the most vulnerable) is more important.

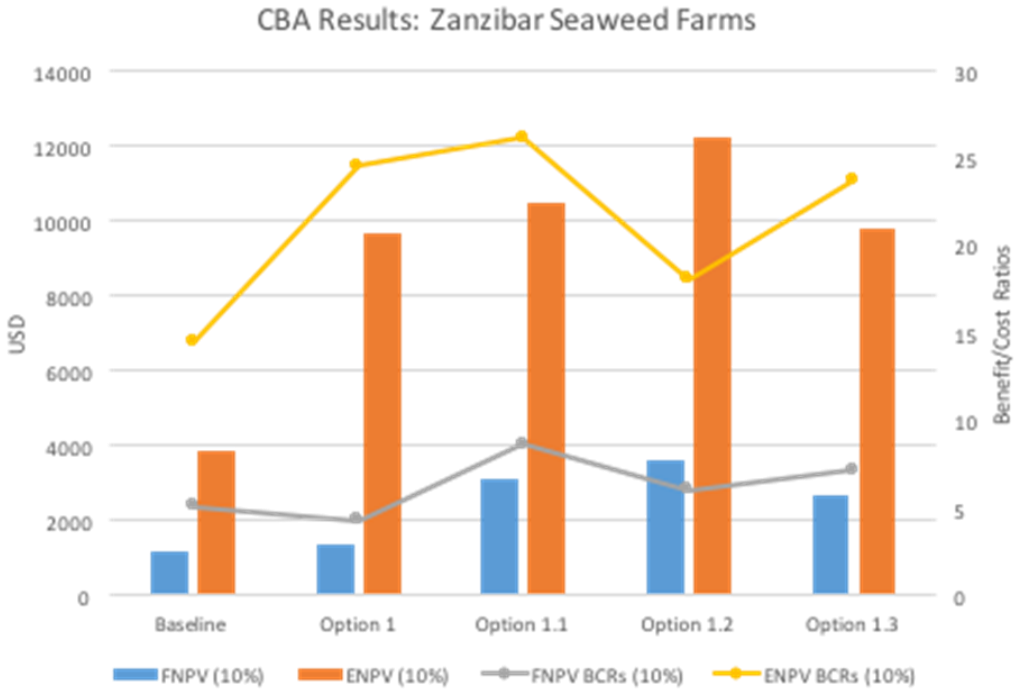
To develop this further, the ECONADAPT project undertook two case studies – focusing on real implementation examples and working with policy makers – and applied and transferred the ECONADAPT methods to economic appraisal. The first case study was focused on agricultural land-use planning and development policy, focusing on mainstreaming climate change into the tea and coffee sectors in Rwanda. Tea and coffee are long lived crops, and current plans to expand production will lock-in land-use for decades, thus the consideration of uncertainty is important.

The case study undertook an economic analysis to investigate adaptation using the ECONADAPT policy approach. The study found strong benefits from investing in early low-regret options that address current weather risks, especially climate-smart options whose benefits increase with climate change. It also assessed future oriented options, using light-touch rule based decision criteria and portfolio analysis to assess the climate smart planting of future tea expansion areas. This considered which areas might be suitable for tea planting given the shifts in agro-climatic zones with climate change. Finally, the case study adopted some iterative risk management (adaptive management) and recommended investment in early monitoring and planning to help inform future decisions (the value of information), especially in relation to emerging pest and disease problems. The analysis was linked to a climate finance application and the economic analysis was used to successfully provide the project justification.

The second case study focused on seaweed farming in Tanzania (Zanzibar). This activity is already being affected by sea surface temperature increases, and as this is a major source of employment for women on the island, there is a need for an early response.

The study identified adaptation options working and undertook an economic and financial appraisal of options, with a CBA, linked to a possible pilot programme. The

analysis identified a series of options with high benefit to cost ratios and the sector is particularly interesting because of the private sector involvement and export potential. The project addressed short-term uncertainties – related to prices, costs or appropriate discount rates –by working with price ranges and using sensitivity analyses.



It also considered long-term uncertainties by assessing investments in information, to provide information, as the basis for longer-term decisions and future major climate change. This used the decision tree concepts from real option analysis and highlighted the need to invest in early sea surface monitoring and long-term planning.

The case studies across the two developing countries – Rwanda and Zanzibar – are designed to have practical use in determining future adaptation investments. Thus, the four products – coffee, tea (Rwanda); seaweed, cloves (Zanzibar) – were selected in conjunction with the principal stakeholders: primarily government ministries, producers and exporters. This process – reported in detail in D9.1 – ensured that the research is more likely to be incorporated in respective sectoral development plans. It also provided a means with which to ensure that adaptation options were developed in the wider policy context that investment decisions are made. An indicator of the effectiveness of this approach is the fact that evolved versions of the coffee and tea analysis undertaken in Rwanda are now being used as the basis for part of an application by the Rwandan Government to the Green Climate Fund established by the UN.

Other principal conclusions are outlined in the following paragraphs.

First, consistent with current practice in development economics, the analyses illustrate the continued importance of estimating shadow prices – market and non-market – for a range of parameters included in the economic analyses. The main market parameters for which shadow prices include the wage rate, distributional weighting, and the discount rate. All constitute a significant form of uncertainty in the analyses, additional

to climate change scenarios. Non-market shadow prices include carbon prices and ecosystem damages. By way of highlighting this point, the seaweed analysis demonstrates the importance of non-market values in climate adaptation interventions. Across all scenarios, appraisals including non-market costs and benefits present much higher returns than financial cash flows alone. This indicates that the adaptation options generate significant social value. Economic, environmental and social benefits of all interventions provide ample opportunity for productive public investment in the sector. Similarly, while global damage assessments have long recognised inequities in climate impacts across regions in the world and between national income groups, they have been less prominent in local analyses. The seaweed case study highlighted gender impacts as an important distributional dimension in the assessment. With distributional weights included in economic valuation, the appraisal demonstrates how a political consideration can be included quantitatively alongside other costs and benefits.

Second, the case studies serve to illustrate that economic decision-support methods that have been developed to better incorporate non-probabilistic uncertainties, of the type presented by climate change projections, can be applied in developing country contexts. In each of the three case studies, these methods – Portfolio Analysis in Rwanda, Real Options Analysis in Zanzibar – are shown to add a further, additional, level of insight to the information that conventional methods such as Cost-Benefit Analysis can convey.

However, third, and as a caveat to the second conclusion, the resource requirements associated with undertaking these more sophisticated methods remain considerable. In the case of the Portfolio Analysis of tea-planting strategies, the data processing was very time-consuming and required a relatively high level of numeracy. The applications of Real Options Analysis – whilst simplified into a decision-tree approach – also required a relatively high degree of knowledge of these methods. It seems, therefore, that the holy grail of "light touch" methods are not quite yet in sight. Certainly, future research needs to focus on simplified approaches to the treatment of uncertainty in adaptation appraisal, as well as effective communication of the results of these appraisals.

WP 10. Toolbox for economic assessment of adaptation

Work Package 10 Objectives

Objectives of the WP are to:

• Develop a methodological toolbox that provides guidance from the methodological tasks and the ECONADAPT case studies to help inform the wider application of the economic assessment of adaptation.

• Prepare a data-repository that includes cost and benefit estimates, especially from the case studies in WP5-9

• Use a policy-centred approach focusing on user needs that incorporates stakeholder involvement throughout

The ECONADAPT Toolbox

In the ECONADAPT project it was the aim of WP10 to develop a methodological toolbox that provides guidance from the methodological tasks and the case studies to

help inform the wider application of the economic assessment of adaptation. During the duration of the project, it was decided to prepare a web-based-version of the toolbox.

From all of the WP10 products, the ECONADAPT Web-Toolbox (http://econadapt-toolbox.eu) is the most comprehensive product. The Toolbox provides easy access to information on the economic assessment of adaptation actions. It is relevant for policy makers and economists looking to implement and adjust methods to their situation or simply for gathering information on how to interpret results and methodological approaches. It provides in particular information on methodologies, data and evidence through case studies (called Insights). While most useful for practitioners and economists, the Toolbox may be of interest to a wider group of experts, stakeholders, and students interested in climate change adaptation. The structure consists of an entry page with four guiding questions which lead the different user groups to the relevant information: focusing on policy challenges in different adaptation situations, background information on different methods suitable for economic assessment of adaptation, detailed information on the case studies/ examples and concrete cost and benefit estimates for adaptation. For further user guidance an "Easy Access Guide" was developed which filters the available information according to six context criteria, which can be selected by the visitor. Feedback from stakeholders was included at different stages in the development of the ECONADAPT Web-Toolbox. There were specific workshops to discuss the targets and structure of the Toolbox in the project team as well as with decision makers. Other workshops and telephone conferences were organized to receive feedback from national, regional and local stakeholders.

The information aims to inform the wider application of economic assessment to adaptation decision-making and thus this has used a two-track approach. There is a first set of information and guidance for a technical audience, i.e. users of economic information. A second set has a more accessible light-touch approach – to ensure broader dissemination and use by a non-economist audience. The toolbox includes more information on the project findings summarised in this document.

The ECONADAPT Library: http://econadapt-library.eu

The library is an online collection of **grey and academic literature** that deals with the **economics of adaptation**. Visitors can use different search functions to narrow down literature with options to search via decision support tool, relevant sector, governmental scale or year of publication. The Library is a living database that will continue to accept **submissions from external authors.** In this way, sets out to collect and make accessible **a broad range of literature** on the economics of adaptation.

The ECONADAPT data repository

The ECONADAPT data repository was developed to include cost and benefit estimates for adaptation measures and with this support the evaluation of climate adaptation activities on different scales. It contains cost and benefits which were compiled and estimated in the ECONADAPT Case study Work Packages 5-9. Furthermore, it includes information from reviews in the methods oriented WPs. It is developed in a web-based format http://econadapt-toolbox.eu/data-sources. The ECONADAPT data repository is part of the ECONADAP Toolbox. For more information on the toolbox see also D10.1: "ECONADAPT Web-Toolbox" which contains an overview on all different toolbox product.

The data repository is structured to deliver an easy access to estimated cost and benefit estimates of adaptation measures but also to interlink with the original documents which contain the estimation method and important assumptions used for the calculation which are essential for interpretation of results. The data repository contains 44 adaptation measures and 230 data sources.

A Description of the Potential Impact and the main dissemination activities and the exploitation of results (10 pages)

As a consequence of the wide-ranging programme of dissemination activities undertaken over the course of the project reported below, we are confident that there is sufficient momentum and awareness of the project for its outputs to continue to have impact in the formulation and design of adaptation projects and policies in future years. The various web-based products – such as the library, the tool-box as well as the deliverables – provide easy access to resources likely to be useful to a range of users.

Significant results to date

ECONADAPT was referenced in UNEP Adaptation Gap Report (2015): Major part of Chapter 3. Project and EC funding acknowledged in report The ECONADAPT Project and EC funding are acknowledged in report. The report received great attention in Lima, where it was presented at five events: the Structured Expert Dialogue on the 3rd of December, the press launch on the 5th of December, a launch side event in the EU Pavilion on the 6th of December, a side event in the Mountains and Water Pavilion on the 7th of December and a climate resilience and business side event as part of the Caring for Climate Business Initiative on the 8th of December. According to UNEP, the report was widely referenced during negotiations. http://www.unep.org/climatechange/adaptation/gapreport2014/

The ECONADAPT project has used review information and summarised these into two chapters for the OECD book Climate Change Risks and Adaptation: Linking Policy and Economics. The ECONADAPT Project and EC funding are acknowledged in report, and the EC and ECONADAPT logo are included on the publication. This includes Chapter 3: overview of costs and benefits of adaptation at the national and regional scale; and Chapter 6: tools to mainstream adaptation into decision-making processes. The book was published in July 2015.

In relation to the UNFCCC Adaptation Committee, ECONADAPT findings are feeding directly into AC discussions - the project is quoted in its recent report: Methodologies for assessing adaptation needs.

ECONADAPT was referenced in UNEP Adaptation Finance Gap Report, 2015
http://web.unep.org/adaptationgapreport/2015

ECONADAPT was presented at the Paris COP21

ECONADAPT was presented at the Marrakesh COP22

The ECONADAPT project is included on the CLIMAT ADAPT site
http://climate-adapt.eea.europa.eu/knowledge/adaptation-information/research-projects/econadapt/

Videos
The ECONADAPT project produced a number of videos.
These included:

- Introduction to the ECONDAPT project
- Adapting Rwanda: A summary of the International case study
- ECONADAPT partners talking about their role in the project.

A number of policy briefs and reports were produced. These included:

- Introduction to the project
- Policy summary of the costs and benefits of adaptation
- Policy report on the costs and benefits of adaptation
- Policy summary of case studies
- Synthesis of the ECONADAPT policy workshop on the Costs and Benefits of Adaptation (submitted to DG Clima)

A final report for policy makers was produced

- ECONADAPT: The Economics of Adaptation Policy Synthesis

An initial newsletter was produced, followed by a regular updated web site

In addition, a large number of direct meetings with relevant policy makers were held – see 11.2 and meetings table.

- The project has had major engagement with these organisations. This included with the EEA: the ECONADAPT project is now included on the EEA Climate-Adapt portal (http://climate-adapt.eea.europa.eu/web/guest/project/econadapt). A number of activities have also been undertaken with the OECD, including the policy workshop.

- Targeted presentations at key meetings. The project has been presented at a large number of major meetings, and has accepted presentations at the ECCA and Paris Common Futures conferences.

Academic publications are listed in Section 4.2

The project website has been up and running since the start of the project, and has been continually updated.

ECONADAPT Policy meetings, dissemination, conferences, publications

Date	Activity / Event / Media	Person / Result
25/11/2013	Meeting with DG RTD with Alessia Pietrosanti and Rossella Riggio.	Paul Watkiss Alistair Hunt Discussion of project implementation and dissemination, protocol for contacting policy partners in European Commission, newsletter, flyers, etc.
6/11/2013	Meeting with Peter Carter from the European Investment Bank to discuss ECONADAPT. Oxford.	Paul Watkiss Discussion with EIB on project and linkages with the project.
28/11/2013	Meeting with Annika Olsson and Malcolm Smart, UK Department for International Development (Adaptation Economics Leads)	Paul Watkiss Discussion of project, and linkages with DfID work (possible co-funding) as well as end-user information.
4/12/2013	Meeting with Michael Mullen, head of adaptation economics, OECD, Paris, France	Paul Watkiss Alistair Hunt Ariella Helfgott
9/12/2013	Meeting with Stephane Isoard and Andre Jol, European Environment Agency, Copenhagen, Denmark	Paul Watkiss Ariella Helfgott Discussion on Climate-Adapt and aligning project to EEA dissemination activities
11/12/2013	Meeting with Nancy Saich, Edward Calthrop; Matthias Zoellner; Peter Carter Matthew Arndt; James Grant at European Investment Bank, Luxembourg	Paul Watkiss Discussion on Bank user requirements for project appraisal, discussion of bank portfolio and project cycle. Policy partner discussion.
21/1/14	Meeting with DG Clima Joan Canton Alfonso Gutierrez Teira Av de Beaulieu 24, 1160	Paul Watkiss, Alistair Hunt, Ariella Helfgott Plus Alessia Pietrosanti Presentation of project Discussion of links DG Clima and other DGs
24/1/14	Meeting with Annika Olsson and Malcolm Smart, UK DFID, London	Paul Watkiss. Discussion of the project, discussion of end user needs around LDC adaptation (Note travel paid for under another project)
31/1/14	Meeting with Craig Davies, European Bank for Reconstruction and	Paul Watkiss

	Development, EBRD, London	
28/3/14	Meeting on DRR and adaptation with DGs in Brussels DG CLIMA (Claus Kondrup) DG ENV (Ioannis Kavvadas: floods) DG ECHO (humanitarian aid and civil protection – including DRR: Yordanka Mincheva)	Paul Watkiss Alistair Hunt Plus Alessia Pietrosanti Presentation on the project
20/6/2014	Meeting with DG REGIO Brussels	Paul Watkiss Alistair Hunt Onno Kuik Plus Alessia Pietrosanti Presentation on the project
18/7/2014	Meeting with Laura Giappichelli, DG DEVCO, Brussels	Paul Watkiss Alistair Hunt Plus Alessia Pietrosanti Presentation on the project
18/7/2014	Meeting with JASPERS team, Hans van Os. Massimo Marra	Paul Watkiss Alistair Hunt Plus Alessia Pietrosanti Presentation on the project
15/9/14	Presentation at the Workshop PACINAS & PATCH:ES Vienna Austria	Project presentation Paul Watkiss
11/12/14	Presentation to DG Agri, Brussels	Alistair Hunt, Ekko van Ierland
26/11/15	Meeting with Rasmus LAURIDSEN EIB	Paul Watkiss Discussion of project
16/12/15	Meeting with Craig Davies, European Bank for Reconstruction and Development, EBRD, London	Paul Watkiss Discussion of project
16/12/15	Meeting with CCC ASC London	Paul Watkiss Discussion of project tkiss

4/2/16	DGRTD, discussion of dissemination activities	Paul Watkiss and Alistair Hunt Project discussion
4/2/16	DG Clima, Brussels	Paul Watkiss and Alistair Hunt Project discussion and use of project findings for EC Adaptation Review 2017
11/2/16	EEA Stephane Isoard, Martin Fussel	Paul Watkiss and Ecologic Meeting with Climate Adapt team and use of project findings for EEA

Policy Workshops and events

Date	**Activity / Event / Media**	**Person / Result**
18/6/14 – 19/6/14	ECONADAPT Expert Workshop on Adaptation Financing and Implementation: Putting Priorities into Practice Paris	Joint workshop organized with the OECD Attended by 61 participants
13/5/15	Conference session European Climate Change Adaptation conference Copenhagen	Joint session organized with the OECD Session on Adapting to a Changing Climate: the Role for Economic Analysis in Policy
9/7/15	Conference session Our Common Future Paris	Joint session organized with the OECD Session on Costs and Benefits of Adaptation: Lessons from Developed and Developing Countries
9/5/16	Conference session Adaptation Futures Rotterdam	Session organized Session on Developing Action Plans and Assessing the Costs and Benefits for Prioritising, Programming and Financing Adaptation in Developing Countries
27-28/9/16	Econadapt policy workshop Brussels	Econadapt policy workshop Presentations from ECONADAPT project team members Audience of policy makers and researchers, focused on European adaptation costs and benefits

ECONADAPT Project Overviews: Conference presentations

Date	**Activity / Event / Media**	**Person / Result**
29/1/14	Adaptation, Green Growth and Urbanization Workshop 28th – 29th January 2014 London	Paul Watkiss presentation
10/3/14	Adaptation Frontiers: Conference on European Climate Adaptation Research and Practice – Lisbon, 10-12 March 2014.	Paul Watkiss Presentation Low and no-regret adaptation. What do we know about options, transferability, uncertainty and economic appraisal from recent research, policy and practice? "
18/6/14	OECD Workshop Expert Workshop on Adaptation Financing and Implementation: Putting Priorities into Practice	Paul Watkiss Presentation
25/9/14	Rotterdam Deltas in Times of Climate Change II Evaluation of adaptation tools	Paul Watkiss Chairman session on economics Introduction session Evaluation of adaptation tools
13/11/14-14/11/14	Venice, JPI Climate Dissemination activity	Paul Watkiss Presentation Discussion: Economics of the Costs and Benefits of Climate Change Impacts and Adaptation
13/5/15	European Climate Change Adaptation conference Copenhagen	Paul Watkiss Presentation
9/7/15	Our Common Future Paris	Paul Watkiss Presentation
12/15	EU Pavilion, COP21 Paris	Presentation Alistair Hunt, Josselin Rouillard
9/5/16 – 12/5/16	Rotterdam	Paul Watkiss, Alistair Hunt Presentations
12-14/7/16	UNFCCC Bonn	Paul Watkiss Presentation

	National Adaptation Plans	
10 November, 2016	EU Pavilion, COP22 Marrakesh,	Presentation Alistair Hunt ECONDAPT project

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