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The Economics of Adaptation

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To find out more about the ECONADAPT project, please visit the web-site: www.econadapt.eu

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Executive Summary

The aim of Work Package (WP) 1C, the *Framing of policy-focussed economic analysis*, is to establish the overall approach of the ECONADAPT project and to provide the key building blocks and guidance for the subsequent work packages. This deliverable, D1.2 *Design of Policy-Led Analytical Framework*, sets out the results of this work package.

The WP aims to provide a conceptual approach (a framework) for considering adaptation, in the context of the ECONADAPT focus on policy and economic assessment. Importantly, this framework has been designed to match end-user needs and be used for practical applications. A key innovation is that it while it proposes a broad, unified approach, it also differentiates between types of adaptation policy problems and applications.

To develop the framework, the WP undertook a number of tasks. The activities included:

- Review of existing practice, identification of the challenges of adaptation, and analysis of policy needs.
- Design of a policy-led framework for ECONADAPT.
- Analysis of the application of the framework for the policy appraisal of adaptation.
- Policy review at the European and International (developing country) level, and identification of policy entry points.

The activities and findings are summarised below:

- The WP commenced with a literature review on the methodological challenges with the economics of adaptation, identifying key issues in moving to practically-focused policy and economic analysis. It identified a number of key problems with previous (earlier) impact-assessment based studies and their estimates of the costs and benefits of adaptation. These included the long time-horizons (and discounting of future benefits), insufficient consideration of uncertainty, the science-orientated focus of existing information, the focus on technical engineering based adaptation/unit costs, and the lack of integration with existing policy.
- The WP then reviewed the emerging literature on how these challenges are being addressed in the adaptation literature, using this information to design the policy framework for ECONADAPT, and the economic assessment of adaptation more generally. This has led to the recommendation for an adaptation-orientated, policy-first approach, with a shift towards iterative adaptive management.
- In practical terms, the framework identifies a number of complementary types of adaptation interventions, covering different challenges (or problems) across different time-periods. These can be combined as a portfolio of early priorities for adaptation. These include:

    1) Early adaptation action to address the <u>current</u> risks of climate variability and reduce the adaptation deficit, to provide early benefits and build future resilience to climate change (i.e. current decisions to address current problems);

2) Mainstreaming adaptation into current infrastructure and plans to enhance the resilience against future climate risks (i.e. current or short-term decisions which will need to consider future climate change including uncertainty); and

3) Addressing the long-term challenges of future climate change, noting the high uncertainty, with a focus on building iterative responses to address future risks (i.e. future uncertain decisions for future uncertain climate change).

- Some examples of these interventions were identified. This was linked to WP1D to inform the literature review on the analysis of the costs and benefits of adaptation.
- The WP then mapped the decision context and applicability of the framework for each of the five policy case study areas (WP5 Disaster Risk Reduction, WP6 project appraisal WP7 Policy Appraisal, WP8 macroeconomics, WP9 international adaptation finance). This allowed a policy centred approach to be developed, focusing on stakeholder and user needs.
- The WP then reviewed how the framework could be applied for decision support for adaptation appraisal, focusing on decision making under uncertainty. The suitability of different approaches to each of the policy themes was also mapped, to link the policy framework to the case studies.
- Finally, the study reviewed the policy context for adaptation appraisal in Europe (WP5-8) and developing countries (WP9), to help align the ECONADAPT policy framework to policy needs. This provides the socio-institutional context and identified entry points for case studies.
- The policy-led framework has been communicated to all the WP teams, and work is ongoing to help the further integration of the approach in the policy case studies.
- The WP has been summarised and will be published as a number of chapters in a forthcoming OECD publication on the economics of adaptation, ensuring a high dissemination impact.

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Abbreviations

Relevant DGS

(AGRI) Agriculture and Rural Development
(BUDG) Budget
(CLIMA) Climate Action
(COMP) Competition
(ECFIN) Economic and Financial Affairs
(ECHO) Humanitarian Aid and Civil Protection
(EMPL) Employment, Social Affairs and Inclusion
(ENER) Energy
(ELARG) Enlargement
(ENTR) Enterprise and Industry
(ENV) Environment
(DEVCO) EuropeAid Development & Cooperation
(SANCO) Health and Consumers
(MARKT) Internal Market and Services
(MARE) Maritime Affairs and Fisheries
(MOVE) Mobility and Transport
(REGIO) Regional Policy
(RTD) Research and Innovation
(SG) Secretariat-General
(TRADE) Trade

Other

EBRD – European Bank for Reconstruction and Development
EIB – European Investment Bank
OECD - Organisation for Economic Co-operation and Development
WHO-E – World Health Organisation Europe
DFID - UK Department for International Development
UNFCCC – United Nations Framework Convention on Climate Change -Bonn

Introduction

WP Description, Aims and Objectives

The objective of WP1C is to establish principles of a policy-led analytical framework. The WP description is outlined below

1C. Description of Work. (PWA, ECOLOGIC) This task will develop a method that leads the economic analyst to contextualise adaptation appraisal within a stakeholder-focussed process, where a wide spread of adaptation actions are considered within current – as well as future – climate variability and change, considering multiple drivers (rather than climate alone). The method will differentiate between types of adaptation policy problems (e.g. from economic appraisal to policy levers), at different aggregation levels (from local to macro-economic), and will anchor policy questions in relation to the specific relevant decision entry points. The task will also consider how best to frame the study to different policy makers, for different types of policy issues, and this task will develop potential policy frameworks to do this. This will involve discussion and co-operation with all the individual partners across the consortium, as well as with end users. The project does not seek to provide one single universal approach to appeal to all adaptation decisions to all policy makers: such an approach is impossible. Instead it will explore different key uses for adaptation economics, in major decisions, each anchored in a different decision perspective (project appraisal, policy appraisal, macro-economic analysis, developing country perspectives), and look to explore how best to frame the use of analysis and information.

Deliverable 1.2 Design of Policy-led Analytical Framework.

Delive-rable Number [61]	Deliverable Title	Lead benefi-ciary number	Estimated indicative person-months	Nature [62]	Dissemi-nation level [63]	Delivery date [64]
D1.2	Design of Policy-led Analytical Framework	12	7.00	R	PU	12

The WP aims to provide a conceptual approach (<u>a framework</u>) for considering adaptation, in the context of the ECONADAPT focus on policy and economic assessment. Importantly, this framework has been designed to match end-user needs and practical applications, while also being academically robust. A key innovation is that it while it outlines a single conceptual framework, it also differentiates between types of adaptation policy problems and applications, and the differing issues and methods that will be needed.

To develop the framework, the WP investigated a number of key areas – and challenges - for adaptation, and then brought the findings together to compile the framework. The key activities included:

- ***Review of existing practice and the challenges of adaptation***. This section sets out the historic practice and existing literature on the economics of adaptation. It highlights why the existing literature does not deliver policy relevant information and economic analysis, thus providing the challenges that the policy-led framework needs to address.

- ***Design of a policy-led framework for ECONADAPT***. This section sets out the recent changes in the framing of adaptation, and how this has changed with the practical implementation of adaptation. This is used to present a policy-led framework for the ECONADAPT study, drawing on the concept of iterative climate risk management and policy mainstreaming. Some analysis of how the policy framework can be applied to different activities is hen included to help support the case studies in identifying practical applications.

- ***Economic project appraisal of adaptation***. This section briefly reviews the approaches for appraising adaptation in policy, using decision making under uncertainty as part of the policy-led framework. It also analyses the potential application of these methods to different decision types, and comments on their potential use in the ECONADPT work packages.

- ***Policy review***. This section reviews the policy context for adaptation appraisal in Europe (WP5-8) and developing countries (WP9), to help identify the policy needs for the ECONADAPT case studies, and to identify possible entry points for the project.

The activities in this Work Package – and reported in this Deliverable - have also benefited from EOCNADAPT co-funding provided by the UK Department for International Development and by the International Development Research Centre[1].

The policy-led framework has been communicated to all the WP teams, and work is ongoing as part of WP1C to help the further integration of the approach in the policy case studies.

The WP has been summarised and will be published as a number of chapters in a forthcoming OECD publication on the economics of adaptation, due in Summer 2015, ensuring a high dissemination impact.

[1] Co-funding was provided by: i) UK Department for International Development, as part of the project '*Early Value-for-Money Adaptation: Delivering VfM Adaptation using Iterative Frameworks and Low-Regret Options'* - this project has been funded by UK aid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies: ii) International Development Research Centre (IDRC), as part of the project '*The Economics of Adaptation and Climate-Resilient* Development' – however the views expressed are entirely those of the study team and do not necessarily reflect the views of IDRC.

Challenges in Applying Economics to Adaptation

There is increasing policy interest in the economics of adaptation. This information is relevant at various geographical levels and for different objectives.

Much of the initial focus in this area has been at the global (aggregated) level, in relation to international negotiations and potential adaptation finance needs (e.g. UNFCCC, 2007: World Bank, 2009). However, as adaptation has moved from theory to practice, i.e. towards implementation, the interest has moved to adaptation policy appraisal in national sectoral policies, programmes and plans, and subsequently to the economic appraisal and prioritization of adaptation programmes and projects at sub-national or local level. The focus here has been on deriving estimates of costs and benefits, as an input to policy and project decision analysis. However, the evidence base in this area remains low (see EEA, 2007; OECD, 2008; Watkiss et al., 2011; EEA, 2012; Agrawala et al., 2011; IPCC [Chambwera and Heal], 2014). Furthermore, deriving these empirical estimates involves methodological challenges (see UNFCCC, 2009) and current estimates therefore differ depending on the methods used, (on which there is no current consensus), the level of future climate change, the spatial, sector, and temporal contexts, and the objectives and overall framework of analysis. These challenges have led to a change in the framing of adaptation, as seen in the shifts from the IPCC 4th Assessment Report (IPCC 2007) to the recent IPCC 5th Assessment Report (IPCC, 2014).

This WP has therefore started with a review of the earlier practice on adaptation, and the methodological challenges, to then frame the design of the ECONADAPT policy-led framework.

Early frameworks and adaptation costs and benefits

Most of the early literature on adaptation, especially on the costs and benefits of adaptation used scenario-based impact assessment (I-A) frameworks (see Carter et al., 2007 for a definition; and UNFCCC, 2009 for a review of applications).

Impact assessment studies adopt a sequential approach, starting with climate model projections of future climate change. This information is combined with socio-economic information (e.g. population) to assess the future impacts and damage costs of climate change (so called impact assessment) using damage functions or impact models. These assessments (sometimes) go on to assess adaptation, focusing on technical solutions that reduce these impacts, and assessing the costs and benefits of action to the defined climate projections, usually to achieve an optimum or acceptable level of adaptation. An example and outline framework is included in the box.

This framework is most commonly applied within an impact assessment method, with the use of impact models or integrated assessment models, and it can also be applied with risk assessment methods in the case of changes in extremes.

These frameworks - and the results of studies that apply these methods - use a *predict-then-optimize* approach (also known as an *'if–then'* approach). This assumes perfect foresight, as future climate scenarios are assessed one at a time (i.e. for a defined future)), with the optimal or most cost-effective level of adaptation (based on costs, benefits and residual damages) assessed for each individual scenario separately.

Impact-Assessment frameworks

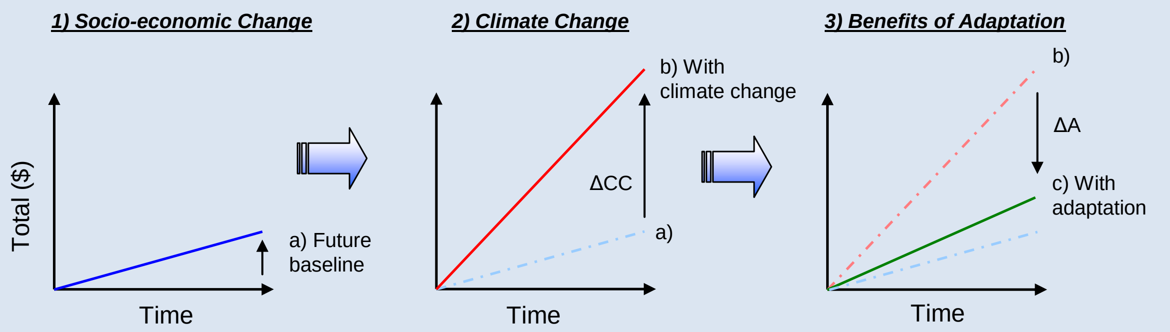
Adaptation costs and benefits are often used to present a high level framework for adaptation assessment, shown in the stylised figure below (based on Boyd and Hunt, 2006). This shows a simple schematic of the economic costs of climate change impacts (vertical axis) against time (horizontal axis) and outlines three steps for assessing costs and benefits:

1. The economic costs are first estimated for the future baseline conditions, shown in (a). This is needed because future impacts are strongly influenced by socio-economic change, due to population growth, increased wealth, land-use change, etc. These changes will occur even in the absence of climate change. Socio-economic change can be as important as climate change in determining economic costs, though they are also uncertain.

2. The additional impact of climate change is added (ΔCC) to give the total economic cost of socio-economic change and climate change together, shown in (b). Strictly speaking, only the marginal (or net) increase above the baseline in 1) is due to climate change. Note that in some cases, socio-economic and/or climate change may lead to economic benefits.

3. Adaptation reduces these impacts (or damage costs), shown in the line moving from b) to (c). The reduction (ΔA) provides the economic benefits of adaptation and this can be compared against the costs of adaptation (note this is not shown in the figure). The line (c) represents the residual damages (economic costs) left after adaptation.

If the economic benefits of adaptation outweigh the costs, then there are net benefits. If not, then this potentially leads to mal-adaptation. However, as shown in the figure, adaptation reduces impacts, but it does not remove them completely (so called residual impacts). The optimal level of adaptation will therefore be a balance between adaptation costs, the benefits and the residual impacts.



Outline and steps of a stylised framework for assessing adaptation benefits

Source: UNFCCC, 2009, adapted from Boyd R. and A. Hunt (2006)

The use of these frameworks primarily focuses on technical or engineering based adaptation options (e.g. dikes for coastal protection, irrigation for agriculture), as unit costs exist for these options, and it is also possible to estimate the reductions in impacts using metrics of effectiveness that can be translated through to a reduction in damage costs. This allows the analysis of the costs and benefits of adaptation, e.g. additional beach nourishment to address coastal erosion or additional irrigation to offset crop yield reductions from climate change. It can also be used to assess the costs of achieving acceptable levels of risk, e.g. adaptation to maintain a 1 in 100 year level of flood protection.

The results from these studies very often conclude that adaptation is very cost-effective / has high benefit to cost ratios. As example, Brown et al (2011), using the DIVA Model for Europe, reports benefit:cost ratios of as much as 10:1 for coastal adaptation undertaken in the 2050s, and above 15:1 for adaptation undertaken in the 2080s.

The problems with using impact-assessment for practical adaptation decisions

While much of the current literature still applies this framework when employing impact models, there are a number of problems associated with approaches in a practical policy context. These relate to a number of issues:

i) The practical policy relevance of the framework;

ii) The assumptions used to derive estimates of costs and benefits;

iii) The representation of practical adaptation;

These are discussed in turn below.

The practical policy relevance of impact-assessment

There are two major issues with the practical policy relevance of impact assessment frameworks – when used on their own - for adaptation analysis.

First, impact-driven studies focus on the long-term future, when major climate shifts occur. Indeed, most climate change modelling has focused on the late century (2050-2100), because this is the time period when a clear climate change signal emerges, relative to the noise of underlying climate variability.

This leads to a problem of timing. Impacts arise in the future, e.g. towards 2050 or beyond, thus the benefits of adaptation also arise (predominantly) in this time period. <u>This means (obviously) that the costs of early adaptation action (today) are high when compared to future discounted benefits</u>. Indeed, at conventional OECD public discount rates, and even more so for developing country discount rates, future adaptation benefits are extremely small in current terms and thus rarely justify adaptation intervention today.

Second, and perhaps more importantly, <u>these scenario-driven impact-assessment approaches ignore uncertainty</u>[2], which represents the key methodological challenge for adaptation (UNFCCC, 2009; Hallegatte, 2009; Wilby and Dessai, 2010). While a focus on decision making under uncertainty has become widespread in the adaptation literature (Adger et al. 2006; Dessai and van der Sluijs 2007), there has been less adoption in economic assessment. The predict-then-optimise method used in impact assessment just avoids uncertainty by assuming the future is known (with foresight) and then optimises (perfectly) to this outcome.

However, in reality there is extremely high uncertainty associated with future climate change, both with scenario and model uncertainty. An example is provided in the box. As there is high uncertainty over future impacts, there is high uncertainty over the future benefits of adaptation. An early adaptation response that addresses a long-term risks (even without discounting) has the potential to

[2] We adopt an economic definition of uncertainty, where it is impossible to attach probabilities to outcomes, as differentiated from risk, where probability is defined.

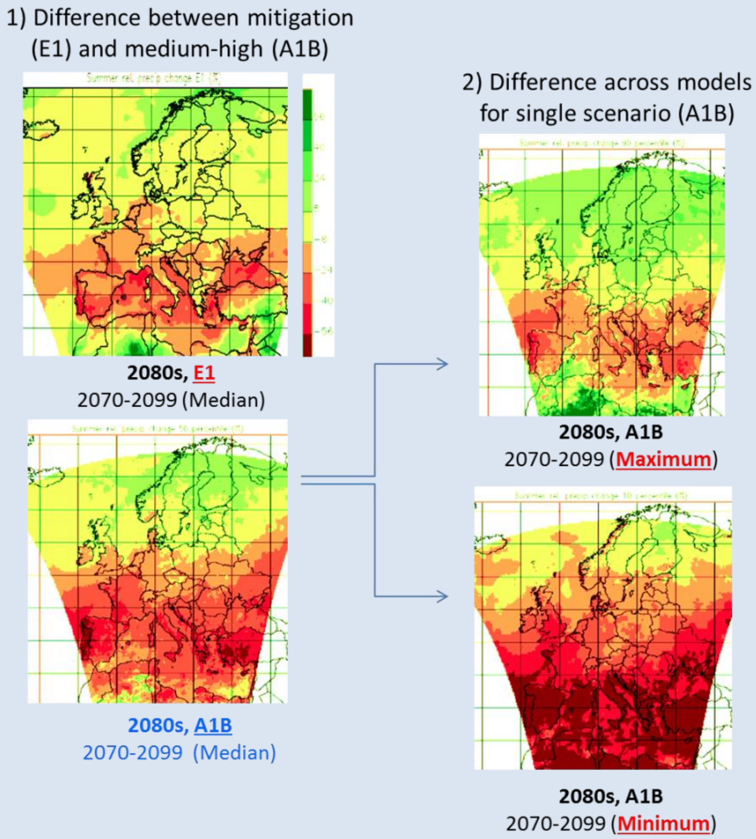
waste resources by over-investing against risks that do not emerge, or implementing measures that are insufficient to cope with more extreme outcomes. This can also lead to the risks of lock-in and stranded assets. It is possible to factor in responses to this uncertainty, but this will usually involve an additional cost.

Uncertainty

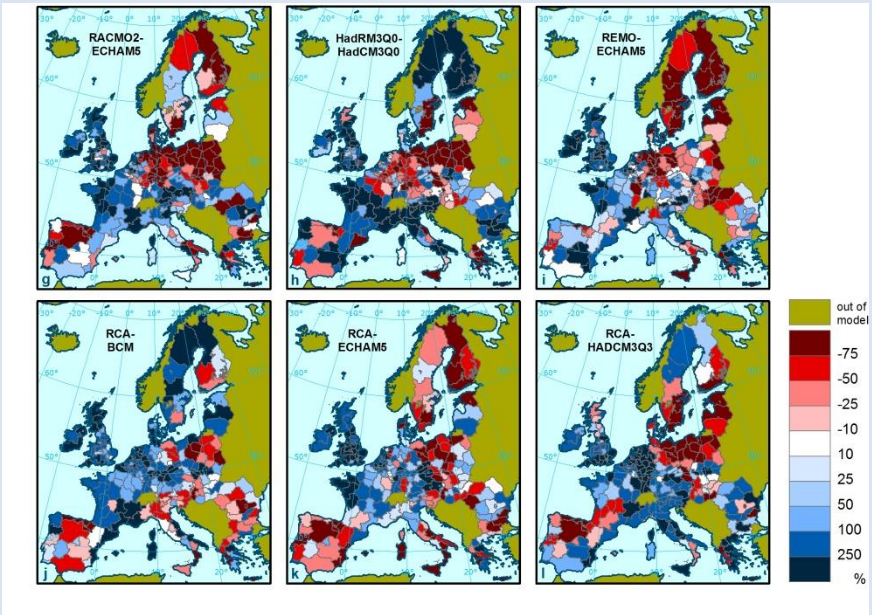
Future climate change projections are uncertain for two key reasons. First, future greenhouse gas emissions – and thus the level of climate change that will occur over time - are uncertain. It is therefore not clear whether the world is on a pathway towards the 2°C goal (2 degrees relative to pre-industrial levels) or, as many commentators consider, a higher emission scenarios consistent with a 3 or even 4°C warmer world. Second, even when a future emission scenario is defined, there are still large differences projected from alternative climate models. This arises because of structure and sensitivity of the models, the regional and seasonal changes associated with global temperature, and the difficulty in projecting complex effects such as rainfall. As a result, different climate models often give very different results even for the same scenario and same location.

This can lead to a very high range of uncertainty. An example is shown below for the change in summer rainfall with climate change in Europe in the 2080s (Top), with a comparison of downscaled regional climate information, across scenarios and models. This shows the change in summer precipitation varies drastically: indeed, for a large transect (from the UK to Romania) the direction of change differs between the driest and wettest and models (shown on the right hand side). This uncertainty is critical for the consideration of adaptation.

These uncertainties cascade through to climate risks and damage costs, and thus to the effectiveness of adaptation responses, show in the bottom figure, which shows the change in expected annual damage (EAD) for 12 RCM simulations input into the same flood damage model, with red and blue colours depicting decreases or increases (respectively) in flood damages. Most countries show significant variation, even in the direction of damage, noting this presents the estimates for defined future scenario (A1B) only. A cost-benefit analysis of the mean change (or probability weighted expected values) will not capture this uncertainty, as it will orientate the optimal response towards minor deviations from the current, even though the direction of change varies across simulations.



Relative change in summer precipitation (%) for summer (June, July and August) in 11 RCM simulations from ENSEMBLES archive, for 1) A1B and E1 median scenarios for 2070-2099 and 2) alternative model projections for the same time period and emissions scenario (2070-2099 for A1B). Source: Christensen et al 2011.



Change in EAD between the A1B 2080s (2070-2099) and baseline period (1961-1990) from LISFLOOD simulations. Each plate represents one of 6 GCM-RCM combinations. Source Rojas et al. 2013.

Estimates of the costs and benefits of adaptation

The estimates of the costs of adaptation / benefits of adaptation that are generated by impact-assessment studies have certain assumptions, that mean they are likely to underestimate costs and over-estimate benefits.

First impact-assessment studies assume the future can be predicted, assessing the costs and benefits of future defined scenarios one at a time, and ignoring uncertainty. Therefore, depending on the method used, the scheme can be designed to give a high ratio of benefits to costs / high cost-effectiveness / the optimal level of adaptation. In practice, ex post out-turns will be very different, and benefits or cost-effectiveness may be lower (or a non-optimal outcome will arise). As an example, if a single predicted increase in sea-level rise is assumed (e.g. 0.3 metres), then it is possible to design and build a sea-wall in a highly cost-effective way (even to an optimal level), taking account of future storm-surge probability and acceptable residual risk levels. However, given actual sea-level rise (SLR) outcomes will differ due to uncertainty, the outcome will be less favourable in practice, i.e. the costs will be higher than needed if SLR turns out to be lower, and residual risks will increase if SLR turns out to be higher.

Related to this, the consideration of uncertainty in adaptation will often necessitate some form of action that will increase the costs or reduce the benefits, when compared to an idealised or optimum scenario. As an example, an option that is better able to perform over a range of future climate scenarios will be more robust, but it will not be as effective as a highly optimised option designed for a single central projection. Similarly, an option that allows some future flexibility to cope with uncertainty may be preferable, but it is likely to have a cost penalty compared to an option that is designed to a single predicted future. These issues can be taken into account in economic appraisal (see later section), but the critical issue is that they involve higher costs or lower benefits compared to an appraisal where uncertainty is ignored.

Second, impact assessment studies focus primarily on technical costs and thus omit a range of opportunity and transaction costs associated with policy implementation. Many studies of adaptation focus on engineering options and use technical unit costs, such as the cost per m^3 of beach nourishment, or the cost per litre of irrigated water. One of the key lessons from the mitigation domain is that the use of these technical costs significantly underestimates actual cost out-turns, because they omit various hidden costs. Two studies provide examples of how important this has been in the mitigation domain. A study by Ecofys (2009) suggests that the hidden costs not usually captured in financial analysis can significantly increase the payback period for selected household energy efficiency measures. More explicitly, Enviros (2006) report that the inclusion of such hidden and missing costs can reduce cost-effective opportunities by between 10-30% in the buildings sector.

These hidden costs vary with the type of adaptation, but the critical issue is that they are not factored into current assessments. As an example, climate smart agriculture options tend to have opportunity costs associated with the loss of land, use of labour, or initial reduction in productivity, which increases costs to farmers (see McCarthy et al., 2011). Furthermore, these and other factors provide important barriers to implementation, which must be overcome, e.g. information and awareness, training and capacity building, technical assistance, up-front access to finance. Addressing these barriers requires some planned policy intervention, even if this is providing the information or creating the enabling environment, and there will be costs associated with this. A further example arises for ecosystem based adaptation for coastal flood protection (see Cartwright et al, 2013), where there can be high opportunity costs from land acquisition, and there are important transaction costs associated with monitoring and enforcement costs to maintain the integrity of these ecosystems to ensure they deliver planned benefits.

Third, impact-assessment studies capture a sub-set of possible impacts, and thus adaptation costs. For example, they may capture the costs of adaptation to protect coastal areas against storm-surges, but may exclude the costs of adaptation to address impacts on coastal ecosystems. Similarly for agriculture, impact studies may look at the level of irrigation or fertiliser use to address changing trends of temperatures and rainfall, but omit the potential effects of changing pest and disease prevalence, or higher soil erosion or flood risk damage from increased precipitation extremes.

These points indicate that the existing impact-assessment literature is likely to underestimate the costs of adaptation and over-estimate the benefits of adaptation. However, the scale of the error is difficult to quantify, not least because the times-scales for climate change do not allow ex post evaluation. Nevertheless, in some sectors, there is data from both older impact assessment studies and more recent policy studies, which allows an analysis of ex ante policy costs with different assumptions.

An example is in the coastal sector, which is the most advanced area in terms of adaptation costs and benefits (OECD, 2008), and therefore provides a reasonable evidence base to explore and cross-compare. Impact assessment studies indicate coastal adaptation (dike protection and beach nourishment) is an extremely effective and low cost adaptation response. Brown et al. (2011) – undertaking an impact assessment with the DIVA model - estimated that the total gross costs of coastal adaptation in Europe would be €1 billion/year by the 2020s (the years 2010 – 2040) rising to €1.5 billion/year by the 2050s and 2080s, i.e. through to the end of the century (A1B mid-scenario, EU, current prices, undiscounted). This delivers a benefit-to-cost ratio of 6:1 in the 2050s and 17:1 in the 2080s. This can be compared to more detailed ex ante appraisals of coastal adaptation that factor in uncertainty, and include more detailed and wider assessments of cost and impact categories. For example, the estimated annual costs for future flood protection and flood-risk management to future climate change over the century in the Netherlands (alone) has been estimated to be in excess of €1 billion per year (Delta Commissie 2008) and a similar annual cost was estimated for the UK to address climate change in the Foresight Study and in the EA long-term investment plan (DTI, 2004: EA 2008: 2011). These detailed studies indicate annual costs per country are similar to the estimated impact-assessment costs for protecting the entire EU.

Furthermore, the relatively high levels of aggregation in most impact studies can omit high local costs. For example, major coastal cities are likely to involve much higher adaptation costs than inferred by aggregate coastal impact studies, especially for port-river cities which require highly engineered protection. As an example, the Modulo Sperimentale Elettromeccanico barrier in Venice has a capital cost of €4.7 billion (Regione del Veneto, 2010), and the costs of protecting London against future sea level rise may require the construction of an additional flood barrier later this century (under a high sea-level rise scenario), which could cost GBP 6-7 billion alone (EA, 2009; EA, 2011), though note these are one-off capital costs rather than annualised values. Hallegatte et al. (2013) analysed 136 global coastal cities and reported indicative adaptation costs of USD 350 million per year per city, or approximately USD 50 billion per year in total. This is similar to entire global cost of adaptation estimated by the most recent coastal impact assessment (Hinkel et al., 2014), which estimated annual investment and maintenance costs of protecting the entire world coast to 2100 in the range of USD 12–31 billion to USD 27–71 billion (for low and high warming scenarios).

These country and city examples indicate much higher adaptation costs when compared to earlier impact assessment studies – in fact over an order of magnitude higher. This is a very large difference. These differences arise for a number of reasons, and include important input assumptions and methods, as well as technical or modelling reasons:

- Estimates of coastal adaptation costs and benefits vary with the level of protection (the objective) and the method used to derive this, whether acceptable levels of risks or cost-benefit analysis: earlier impact assessment studies assume modest protection levels that are below existing protection standards in some OECD countries. As an example, the Netherlands has a 1 in 10000 year level of protection, while London is currently protected to a 1 in 1000 year level of protection. Maintaining higher current protection levels under future climate change will lead to higher adaptation costs, but it is important to note that existing levels of protection have been set on the basis of societal preferences.
- As highlighted above, impact assessment studies assume foresight - the models are run for one scenario at a time - and thus do not consider uncertainty. Many of the higher costs in the detailed studies are driven by scenarios that include more extreme sea level rise (i.e. projections of 1 metre or more), as these lead to sharp increases in damage and adaptation.
- National and city studies include more categories of impacts (e.g. ecosystem), that involve trade-offs or additional measures. The also include opportunity and transaction costs associated with implementing the policies, or associated with the process of design, consultation and construction. In many cases, complex engineered city or tidal barrier systems are needed, which have much higher costs than simple dikes, but allow river or tidal flows which area critical to other users or systems.

However, balanced against these higher cost drivers, it is also clear that a much wider range of types of adaptation will be implemented, including capacity building and soft (non-engineering based) measures. Some of these options will have lower costs than engineering based options (Agrawala et al, 2011), e.g. water conservation measures at a community level, or they may offer co-benefits, thus in such cases, technical adaptation costs from impact assessment studies could actually be over-estimates of ex post out-turns, due to the choice of lower cost alternatives. It would also be expected that adaptation costs would fall as implementation increases in scale and learning occurs, as well as more innovative and low cost solutions emerge.

Finally, it is stressed that all these studies – both earlier impact-assessment studies and later policy studies - assume that adaptation is perfectly implemented, i.e. that options work and are maintained to provide efficient outcomes, that cost estimates are accurate (failing to take account of optimism bias), and that adaptation is implemented within an effective governance and implementation framework. In many contexts – but particularly in developing countries - this will not be the case, and the potential for mal-adaptation, misallocation of resources, and projects that do not deliver as expected, will arise. This will further increase adaptation costs, or reduce adaptation effectiveness and benefits, compared to ex ante estimates.

Moving to practical adaptation

A large body of theoretical and practical literature (e.g. Füssel and Klein, 2006; UNFCCC, 2009: Watkiss and Hunt, 2011) has identified that impact-assessment based approaches are useful for raising awareness, and generating headline estimates of the costs and benefits of adaptation, but concluded they are not useful for informing practical adaptation (i.e. for implementation). This is because such studies have:

- Insufficient consideration of immediate and short term time-scales – noting that impact assessment studies are future focused towards the longer-term;

- Insufficient consideration of wider (non-climatic) drivers and existing policy;
- Insufficient knowledge of future climate conditions(and the dynamic nature of climate change) on the temporal and time-scale relevant for adaptation decisions;
- Insufficient consideration of the full diversity of adaptation options – focusing instead on a narrow set of options that can be costed;
- Insufficient consideration of the factors determining the adaptation process itself, including adaptive capacity;
- Insufficient consideration of the key actors and of the policy context for adaptation.

Set against these issues, the historic focus on estimating and compiling engineering-based adaptation costs and applying these in impact-assessment based frameworks does not meet the needs of decision-makers and so is insufficient to support practical (near-term) adaptation implementation.

As a result, the adaptation literature (grey and academic) has evolved significantly over the past few years, which is reflected in the recent IPCC 5th Assessment Report. These changes are discussed in the next section.

Designing a Policy-Led Framework for ECONADAPT

In response to the issues outlined above, a number of key shifts have emerged in the adaptation literature (grey and academic) over recent years. These have direct relevance for the economics of adaptation and for the design of the policy framework in ECONADAPT. These include:

- The move away from impact/vulnerability assessment to adaptation assessment;
- The differentiation of adaptation applications and problem types;
- The increased policy focus and the move towards mainstreaming;
- The emergence of iterative climate risk management (decision making under uncertainty);
- The growing awareness of the importance of socio-institutional issues and the barriers to adaptation.

These are discussed in turn below.

Adaptation Assessment

A number of approaches have been used to consider climate change impacts (rather than mitigation), which can be broadly split into climate change impact, vulnerability and adaptation (CCIVA) studies (Carter et al, 2007), summarised below.

Some characteristics of different approaches to CCIVA assessment

	Impact	Vulnerability	Adaptation	Integrated
Scientific objectives	Impacts and risks under future climate	Processes affecting vulnerability to climate change	Processes affecting adaptation and adaptive capacity	Interactions and feedbacks between multiple drivers and impacts
Practical aims	Actions to reduce risks	Actions to reduce vulnerability	Actions to improve adaptation	Global policy options and costs
Research methods	Standard approach to CCIAV Drivers-pressure-state-impact-response (DPSIR) methods Hazard-driven risk assessment	Vulnerability indicators and profiles Past and present climate risks Livelihood analysis Agent-based methods Narrative methods Risk perception including critical thresholds Development/sustainability policy performance Relationship of adaptive capacity to sustainable development		Integrated assessment modelling Cross-sectoral interactions Integration of climate with other drivers Stakeholder discussions Linking models across types and scales Combining assessment approaches/ methods
Spatial domains	Top-down Global -› Local	Bottom-up Local -› Regional (macro-economic approaches are top-down)		Linking scales Commonly global/regional Often grid-based
Scenario types	Exploratory scenarios of climate and other factors (e.g., SRES) Normative scenarios (e.g., stabilisation)	Socio-economic conditions Scenarios or inverse methods	Baseline adaptation Adaptation analogues from history, other locations, other activities	Exploratory scenarios: exogenous and often endogenous (including feedbacks) Normative pathways
Motivation	Research-driven	Research-/stakeholder-driven	Stakeholder-/research-driven	Research-/stakeholder-driven

Source: Carter et al, 2007

In recent years, there has been a move away from impact assessment towards a focus on adaptation assessment, consistent with a move towards adaptation policy implementation. These adaptation assessments have a greater focus on the processes of adaptation and on practical actions. They also tend to more similar to vulnerability analysis – rather than the top-down (i.e. climate projection driven focus in impact assessment), though the better studies combine elements of both vulnerability and impact assessment studies, as reported in UNFCCC, 2009).

These adaptation assessment studies[3] still use information from vulnerability or impact assessment, but adaptation plays the central role in the objectives and overall analysis, i.e. these studies are focused around the identification and implementation of adaptation as the starting point, within the context of broader policy and development, and consequently have a much shorter time focus. The move towards adaptation assessment is therefore a key element for the ECONADAPT policy framework.

The broad set of steps in an adaptation assessment have been identified, and summarised in guidance such as the PROVIA and Mediation projects[4]. These outline a broad policy cycle for adaptation, summarised around five steps.

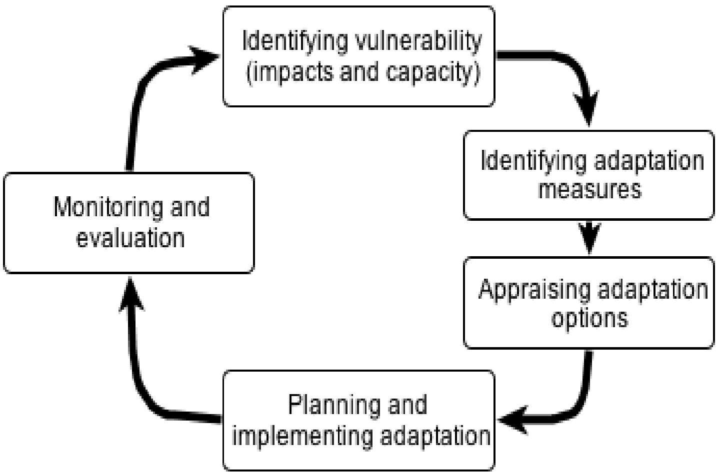
i) identifying vulnerability and impacts;

ii) identifying adaptation measures;

iii) appraising adaptation options;

iv) planning and implementing adaptation; and

v) monitoring and evaluation.



The Adaptation Policy Cycle: Source Hinkel and Bisaro, 2013.

[3] The IPCC definition of adaptation assessment is not particularly enlightening, i.e. the practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.

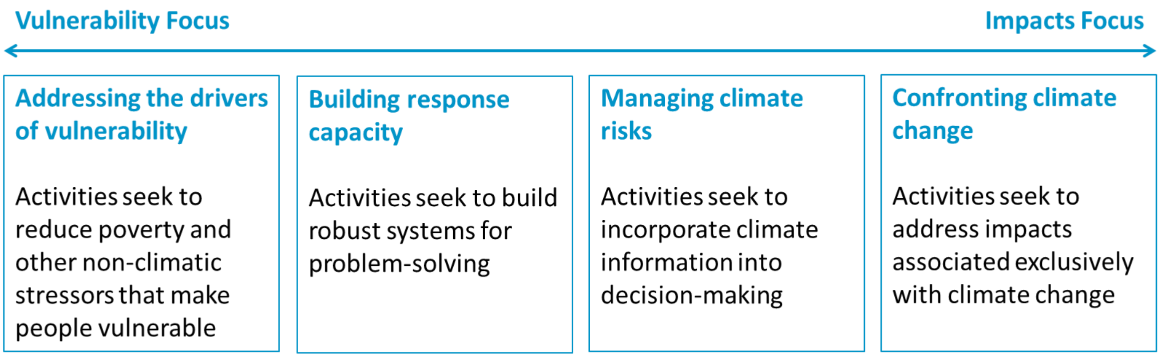
[4] Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) is a global initiative which aims to provide direction and coherence at the international level for research on vulnerability, impacts and adaptation (VIA). http://www.unep.org/provia/
Provia was supported by the Mediation Project (Methodology for Effective Decision-making on Impacts and AdaptaTION). This project provided scientific and technical information about climate change impacts, vulnerability and adaptation options, including the adaptation learning cycle, methods, decision support and information. http://mediation-project.eu/

While this gives a broad outline of steps, it still provides a rather generic framework for adaptation. This has been progressed with the recognition of different types of adaptation problems and responses, discussed next.

Dynamic adaptation / building blocks (problem types)

The recent focus on practical adaptation has moved to a more differentiated framework being developed. This has a number of elements (Watkiss and Hunt, 2011).

- Adaptation is now viewed as a more dynamic process, which starts with the consideration of current climate variability and the existing adaptation deficit (broadly defined as the failure to adapt adequately to existing climate risks) and then considers future climate change over longer time-periods, including uncertainty.
- Greater consideration is given to wider (non-climatic) drivers, current policies, institutional and governance issues, rather than focusing on climate information alone. Unlike mitigation, adaptation does not have a single goal, and the mainstreaming of adaptation involves embedding adaptation decisions within multiple sectors and decision contexts.
- There is recognition that adaptation involves a broad set of response types, addressing different problems. This then separates activities such as addressing current climate variability from action to enhance resilience, or from tackling longer-term challenges (from McGray et al, 2007: Klein and Persson, 2008 as shown in the figure below).



Adaptation as a continuum from addressing the drivers of vulnerability to confronting the impacts of climate change. Source: Klein and Persson (2008).

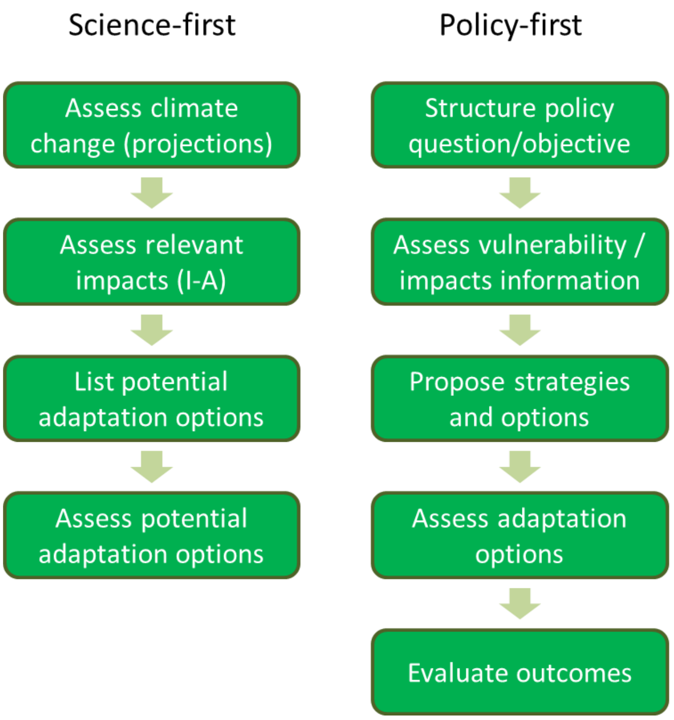
This shift is reflected in the latest vulnerability, impacts and adaptation guidance, e.g. as with the PROVIA initiative. This has moved from the earlier IPCC common impact assessment method, to a set of decision trees that involve the user defining the adaptation problem and the objectives, and looking at the information and methods that might be relevant for a specific context. The consideration of adaptation as a series of activities is therefore a key element for the ECONADAPT policy framework, noting that this will infer difference between the various policy case studies.

Policy focused analysis and mainstreaming

The principle framing for impact assessment is a scientific (science-first) approach. Such an approach is deterministic; beginning with climate change projections and ending with a wide range of impacts that are used to frame adaptation options. As highlighted above, uncertainty is not addressed, indeed it is actually compounded at each stage of the analysis) (Dessai and Wilby, 2010: Ranger et al, 2010; Wilby, 2012).

These studies also undertake assessment from an abstract perspective, i.e. they do not include existing policies by constructing a 'with policy' baseline, and do not consider the existing institutional and governance context, economic decision support methods and objectives already in place within the sectors where adaptation policy decisions are to be made (Watkiss and Hunt, 2011). For this reason, they do not align to standard policy and project appraisal guidance.

An alternative approach, which addresses these issues, has been described as a policy-first approach (Dessai and Wilby, 2010: Ranger et al, 2010). This begins with a suite of adaptation options that may be socially, economically and technically feasible, and then evaluates their performance using quantitative sensitivity testing or narrative scenarios. A variation is a policy orientated approach (Watkiss and Hunt, 2011), which tries to undertake the assessment within the usual policy or project appraisal framework, thereby considering overall sectoral or policy objectives, as well as adaptation objectives, contextual factors, and other policy and socio-economic drivers, including demographics and technologies, as well as "softer" cultural aspects. These policy orientated assessments also ensure the existing economic appraisal practice in place in the sectors / organisation is incorporated. This shift is characterised in the figure below, moving from the left-hand side "science first" process to the right-hand side "policy first".



Science-first vs Policy-first / Policy-orientated approaches

Source: Adapted from Dessai and Hulme (2007) and Ranger et al. (2010).

Most national climate change and adaptation studies to date have progressed down the impact assessment route, using a science first approach, as found by Wilby (2012) in a review of policies in the OECD, shown below.

Examples of national risk assessment and adaptation programmes.

Country	Report	Year	Lead agency	Type
Australia	*Climate change risks to Australia's coast: A first pass national assessment*	2009	Department of Climate Change	I-A
Belgium	*Belgian national climate change adaptation strategy*	2010	Flemish Environment Nature and Energy Department	II-A
Canada	*From impacts to adaptation: Canada in a changing climate 2007*	2008	Natural Resources Canada	II-C
Denmark	*Danish strategy for adaptation to a changing climate*	2008	Danish Energy Agency	IV-D
Finland	*Evaluation of the implementation of Finland's National Strategy for Adaptation to Climate Change 2009*	2009	Ministry of Agriculture and Forestry	IV-D
France	*French National Climate Change Impact Adaptation Plan 2011-2015*	2011	Ministry of Ecology, Sustainable Development, Transport and Housing	I-A
Germany	*German strategy for adaptation to climate change*	2008	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	I-A
Iceland	*Iceland's Climate Change Strategy*	2007	Ministry for the Environment	I-A
Ireland	*Ireland National Climate Change Strategy 2007-2012*	2007	Department of the Environment, Heritage and Local Government	I-A
Japan	*Wise adaptation to climate change*	2008	Ministry of Environment	II-A
Netherlands	*Working on the delta: Acting today, preparing for* tomorrow	2012	Ministry of Infrastructure and the Environment; Ministry of Economic Affairs, Agriculture and Innovation	IV-D
Spain	*Evaluación Preliminar de los Impactos en España por Efecto del Cambio Climático*	2005	Ministerio de Medio Ambiente	I-A
Sweden	*Sweden facing climate change – threats and opportunities*	2007	Swedish Commission on Climate and Vulnerability	I-C
Switzerland	*Stratégie Suisse d'adaptation aux changements climatiques: Rapport intermédiaire au Conseil federal*	2010	Département fédéral de l'Environnement, des Transports, de l'Energie et de la Communication (DETEC)	I-A
UK	*The UK Climate Change Risk Assessment 2012 Evidence Report*	2012	Department for Environment, Food and Rural Affairs	I-A
USA	*Scientific Assessment of the Effects of Global Change on the United States*	2008	US Global Change Research Program; Committee on Environment and Natural Resources, National Science and Technology Council	II-A

Source Wilby, 2012. Key:

A: Studies which draw together the current state of knowledge on climate change and to inform rather than deliver specific actions.

B: Studies which assess national risks, linked to appropriate responses and preparedness, often in relation to discrete major hazards (as opposed to climate trends).

C: Studies which assess vulnerability, including to present climate variability.

D: Studies which advance adaptation actions, typically involving significant levels of local stakeholder engagement.

I - Focus on delivery of specific pre-defined information on risks using scientific, usually quantitative methods. Dominated by procedures in 'exact sciences' (including uncertainty analysis) and pragmatic application of risk assessment.

II- Risks and risk factors are treated as (idealized) realities and information is assumed value-free. Strong emphasis on factual and quantifiable information, wide array of different attempts to measure and specify risks.

III- Focus on the use of specific information following predefined decision rules. Formalized assessment procedures exist for individual risks and receptors but procedures are weakly developed for multiple, cumulative or complex risks. Procedures for the clarification and account for management and social aspects are typically undeveloped.

IV- Concerned with the relations, causes and significance of risks. Information is political. Policy arguments are mixed with and covered by scientific rhetoric.

Wilby (2012) reports there is a distinction between those studies that have adaptation thinking at the forefront (Types III and IV, e.g., Denmark and Sweden) and those that begin from a climate science/impact perspective (Types I and II, e.g. Australia, USA). Overall, he concludes that most national assessments are science-first studies (Types I and II) that assemble information on risks to inform adaptation (Category A). There are relatively few vulnerability-based (Category C) assessments – Canada and Sweden being rare examples. The most distinctive work on policy-first, adaptation options appraisal belongs to The Netherlands: this is discussed in the later policy review chapter. However, this is changing, as countries start to move towards national adaptation action plans, and start to mainstream (integrate) adaptation into sectoral policies (as evidenced at the OECD/ECONADAPT Policy Workshop in June 2014).

Similarly, there is also a greater focus on policy alignment and mainstreaming in developing country adaptation, including in the National Adaptation Plan Guidance (Least Developed Countries Expert Group, 2012). This anticipates the integration of adaptation within national and especially sector development plans.

This shift is critical because it means that adaptation assessments will vary with the country and sector context, i.e. there will not be a common single approach used for analysis, as is generally the case for mitigation (where marginal cost curves dominate). Thus, adaptation assessment will need to adjust to fit the existing landscape (though with some changes to accommodate the specific challenges). The shift towards a policy-first approach is therefore a key element for the ECONADAPT policy framework.

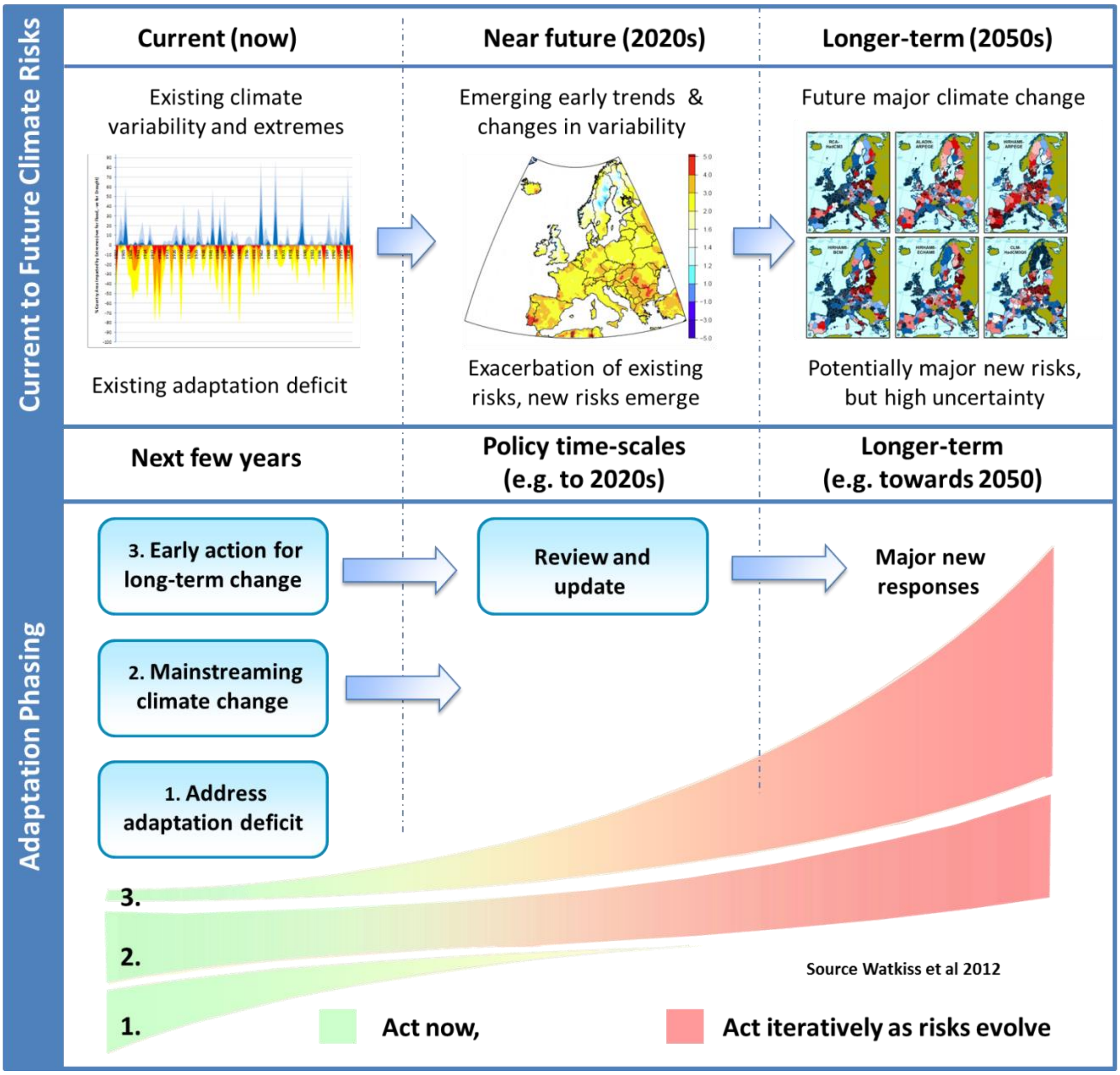
Iterative Adaptive Management (Iterative Climate Risk Management)

To address the issue of early action and long-term uncertainty with climate change adaptation, there is now focus for starting with current climate variability and extreme events (such as rainfall variability, droughts, floods and tropical storms) often known as the 'adaptation deficit'. These events already cause large economic impacts, even in developed countries. Addressing this deficit therefore provides immediate economic and livelihood benefits and also enhances resilience to future climate change. It is also recognised that adaptation (to future climate change) will be less effective if current adaptation deficits have not been addressed (Burton, 2004).

However, while reducing the deficit is generally beneficial, there are some caveats. An existing adaptation deficit exists in all countries, even in highly developed economies of Europe (such as the UK, see ASC, 2011). This reflects the increasing costs of reducing residual impacts / the adaptation deficit towards zero, i.e. it is not cost-effective (or optimal) to reduce the adaptation deficit completely. This may be because of other more effective means of coping with residua risk (risk transfer and insurance) or because the increasing costs do not justify the anticipated benefits.

At the same time, the high uncertainty associated with future climate change is now recognised, and in response, the use of more flexible frameworks is being advanced, that allow learning and iteration through adaptive management (a cycle of monitoring, research, evaluation and learning process to improve future management strategies/decisions).

These aspects can be brought together in a new overall framework for climate change adaptation, illustrated in the Figure below. The framework starts with climate change (top), which is split into a number of linked risks, each related to different policy problems and time-scales. This starts with current climate variability and extremes (top left), i.e. the adaptation deficit. Over time, climate change will affect these existing impacts, and lead to major new risks (top right), though often with high uncertainty. In response, an adaptive management framework has been recommended for adaptation (bottom), also known as iterative climate risk management (IPCC SREX, 2012: IPCC, 2014) or adaptation pathways (Downing et al, 2012).



An iterative climate risk management framework for adaptation.

Source Watkiss et al 2014.

These involve a shift away from a classical optimisation framework (i.e. a predict-and-optimise approach where future climate is predicted, then an optimised adaptation response is advanced, as used in impact assessment) towards a more dynamic view of climate change, and an iterative approach for adaptation. The move towards iterative risk management is therefore recommended for the ECONADAPT policy framework.

The adaptation response involves complementary responses that cover different challenges across the time-periods and climate challenges. Three broad sets of complementary activities have been identified and shown in the Figure above (Watkiss et al, 2011: 2014):

1) Addressing current risks. The first area targets the current adaptation deficit, to reduce the impacts of climate variability. This often includes interventions termed no- or low-regret measures, which are good to do anyway (even without climate change) but also build resilience for the future.

2) Mainstreaming climate into policy and infrastructure (e.g. to address future exposure). The second area targets short-term decisions with long life-times, i.e. which will be exposed to climate change in the future (e.g. infrastructure, development planning decisions). This can be addressed using risk screening and mainstreaming, with early priorities around low-cost robustness or flexibility, supported by the necessary information/capacity.

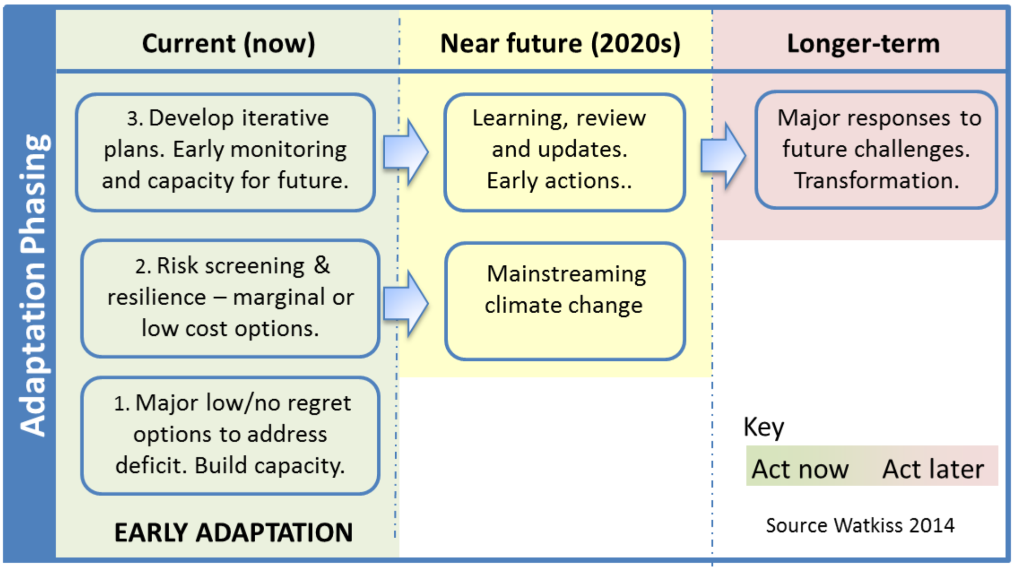
3) Building iterative responses to address future long-term risks. The final area addresses the long-term (and uncertain) risks of future climate change, building iterative response pathways using a framework of decision making under uncertainty and identifying early action to allow learning for future decisions. This allows responses to evolve over time (with a learning and review cycle) so that appropriate decisions can be taken at the right time, allowing for action to be brought forward or delayed as the evidence and observations (of climate change) emerge.

In many cases, a strategic adaptation programme will comprise of a portfolio of interventions that cover all of these different aspects.

Variations on these themes exist in the literature, e.g. there may be further sub-divisions, or alternative terms, but the key thing is around the timing of responses: type 1 activities are associated with current actions and current risks; type 2 activities are associated with current actions with current and future (uncertain) risks; and type 3 activities are associated with future actions and future (uncertain) risks) as well as issues of future option value and lock-in. This also leads to different issues in relation to discounting, future treatment of uncertainty, etc. between the three categories.

Due to their differing nature, the three types of action may require different economic methods to assess. The balance of activities in each of three categories will also vary. Early interventions to tackle the adaptation deficit will focus on concrete action, while early actions for type 2 will involve a greater focus on risk screening, marginal changes, flexibility and robustness, and finally, type 3 activities will focus on early planning, information and evidence gathering, rather than large-scale action or major investment. This is illustrated below.

Alongside this overall framework, there has been a move towards the analysis of uncertainty in decision support and decision-support tools. This is covered in the next chapter on project appraisal.



The early focus for adaptation pathways.

Source Watkiss, et al, 2014.

Socio-institutional processes and the barriers / limits of adaptation

Alongside the issues above, there is also a growing recognition in the mainstream academic literature on adaptation of the role of socio-institutional issues. The IPCC special report on extreme events (IPCC, 2012) confirms the viewpoint of adaptation as a socio-institutional process, defining adaptation as a *process of adjustment* to the actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.

There is also an increasing body of research on the role of socio-institutional networks in climate adaptation. Berkhout et al., (2006) found that many of the resources required for carrying out the process of adaptation lie outside the boundary of a particular organization, and Moser and Ekstrom (2010) report that barriers to adaptation often arise from institutional and cognitive constraints. Downing (2012) contrasts a predict-and-provide viewpoint with a process-based understanding of adaptation.

These studies highlight that the governance and socio-institutional landscape, as well as based levels of capacity, are influential in determining how (and if) adaptation will occur. Following from this, it is important to identify the existing landscape, underlying governance issues, the barriers to adaptation and feedback processes, to speed up the necessary 'climate-adapted routines and capability to be developed' (Berkhout et al., 2006) and thus the delivery of effective adaptation. Indeed, such barriers are one of the key reasons why adaptation options are not already implemented.

In this regard, there are important economic distinctions regarding the roles of public and private actors in adaptation, as well as further distributional aspects in the relative burden of adaptation between the public and private sector.

Both private and public sectors will have a role to play in the development and implementation of adaptation measures (IPCC, 2014). Autonomous adaptation will be carried out by private individuals and the private sector in response to climate change. Moreover the use of the private sector to deliver adaptation will help ensure efficient and effective implementation, and it is recognised that there may be potential for private agents to supply public adaptation given appropriate institutional arrangements for policy instrument implementation (Tompkins & Eakin (2012)).

For example, many adaptation actions create public goods that benefit many and in such cases the implementing party cannot typically capture all the gains, such as if a private or individual agent pays for coastal protection, where the benefits will go to many (Chambwera and Heal, 2014). In turn, this calls for public action. Further, in some cases, private adaptation will not produce socially desirable levels of adaptation, or may lead to externalities, or will not occur due to various costs, incentives, nature of beneficiaries, other barriers and resource requirements. There is therefore an important role for the public sector in adaptation.

As highlighted later, the EC has outlined the public role for adaptation in the Adaptation White Paper and 2013 Strategy. However, it is worth investigating the role for public sector intervention for adaptation, directly, or as an enabling mechanism for private sector adaptation (or autonomous adaptation). The UK Government investigated this (Defra, 2010) and set out that people and businesses will take action to adapt when it is in their interest and power to do so; that is, they will take measures where the benefits outweigh the costs to them. However, the guidance also stresses that there are a number of information, market and policy failures that act to prevent such action, and this is borne out by the lack of autonomous, proactive adaptation seen to date in a number of sectors (Berrang-Ford. et al 2011). The Defra report highlights that there are a range of barriers that make it challenging for people and businesses to choose the right adaptation strategy, including:

- Market failures. These include lack of information or awareness of climate impacts, misaligned incentives and the public good nature of some adaptation measures.

- Adaptive capacity. Some people lack the ability to respond to climate change because of financial or other constraints.

- Natural capacity. Natural systems might be unable to adapt because of the natural pace of their adaptive capacity, their resilience to frequent stresses, and the surrounding environment.

- Behavioural barriers. Adaptation decisions are complex, and involve dealing with long time horizons and uncertainty. Taking into account climate change in decisions made today – such as how and where to build new infrastructure – will have long-term benefits, but may entail additional near-term costs. There is a tendency for people to demonstrate inertia, procrastinate, and have implicitly high discount rates that place little weight on the future consequences of their decisions.

<u>The consideration of such barriers is important for the ECONADAPT project, especially where they related to market or policy failures.</u>

Finally, two additional aspects have emerged, that cross the barriers of technical, economic and socio-institutional aspects.

In the 5th Assessment Report (IPCC, 2014), the IPCC differentiated the future types of adaptation into incremental versus transformational adaptation. Incremental adaptation involves actions where the central aim is to maintain the essence and integrity of a system or process at a given scale. Transformational adaptation changes the fundamental attributes of a system in response to climate and its effects.

Alongside this, there was a greater focus in the report on the limits to adaptation, i.e. in the ability to reduce the future impacts of climate change. While there are clearly adaptation limits in relation to the major catastrophic impacts or tipping points identified in the impacts literature (Lenton et al, 2008: Kriegler et al, 2009: Levermann et al, 2012) there is now also a growing recognition that there will be limits to adaptation across the range of more conventional future scenarios, related to individual sector or geographical contexts. It follows that failure to recognise these limits in policy analysis will over-estimate the potential for adaptation (and the balance of incremental versus transformative adaptation).

The IPCC discussed the following five types of limits to adaptation (Adger et al, 2007) physical and ecological limits, technological limits, financial barriers, information and cognitive barriers, and social and cultural barriers. The physical and ecological limits are absolute limits (and are particularly relevant in the context of major extremes). For example, the rate of sea-level rise determines whether or not healthy coastal ecosystems such as salt marshes can adapt by growing landwards and upwards. Beyond a certain rate these ecosystems will not be able to 'keep pace'. The other four types are mutable and therefore closely related to adaptive capacity. The fact that the latter three types are referred to as barriers already suggests the nature of limits. As an example limits in human systems are not absolute, but rather the points beyond which people can no longer meet their adaptation objectives, or where adaptation can no longer avoid a situation in which people's needs and values are compromised due to climate change. These limits will vary geographically: a certain level of salt-water intrusion into groundwater could make land unsuitable for agriculture in some places, whereas s technology might be available to manage groundwater flows and thus avoid impacts in others. Limits may also be normative; for example, societies that have agreed on safe minimum standards and minimum levels of service provision (*e.g.* flood protection, water supply) might find that climate change limits their ability to meet these standards and levels.

Bringing the ECONADAPT Framework Together

Based on the sections above, a number of key shifts have emerged in the adaptation literature (grey and academic) for adaptation policy and economics. These have been used to design the policy-led framework for ECONADPT. They include:

- A move away from standard impact/vulnerability assessment towards adaptation assessment, i.e. where the overall analysis is framed from the objective of adaptation.
- The differentiation of adaptation (applications) into types of applications over time and scale, separating the current, short and longer-term, and addressing different objectives (e.g. mainstreaming resilience into ongoing activities versus targeting future climate change).
- The mainstreaming of adaptation in the current policy and development landscape, i.e. recognising that adaptation is not usually the primary driver for the decision and aligning the assessment to existing sectoral or development norms;
- The emergence of adaptive management and iterative climate risk management, which starts with the current adaptation deficit and then looks at future climate change under a framework of decision making under uncertainty. This also means a broader set of adaptation options, including capacity building, the value of information, and options/processes that help address future uncertainty.

- The recognition of socio-institutional issues and the barriers to adaptation (i.e. adaptation as a process).

The inclusion of these aspects in the policy framework aligns with the recent IPCC 5th Assessment Report, in the Chapter on the Economics of Adaptation (Chambwera and Heal [Eds]: IPCC, 2014), which reports that *adaptation has evolved from a focus on cost-benefit analysis and identification of "best economic" adaptations to the development of multi-metric evaluations including risk and uncertainty*.

Some additional detail on the framework is provided in the Appendix.

Linking to the ECONADAPT Work Packages

The implications of the framework for each of the ECONAPT case studies are outlined below:

- There will be a need for information on the costs and benefits of non-technical options, especially with respect to the value of information and soft (non-technical) options in WP2.
- For WP4 on uncertainty, the shift to decision making under uncertainty will be key. This is discussed further in a subsequent chapter.
- For all the case studies, it will be important to apply a policy first approach, and ground the assessments within the relevant applications and broader context.
- For WP5 Disaster Risk. This is likely to have a strong focus on addressing the current adaptation deficit – especially where soft or capacity building measures are involved. This will be a particular issue for New Member States. For hard adaptation, there will be some longer-lived elements which necessitate mainstreaming, i.e. to consider future climate change. There is also some relevance for longer-term planning to changing extremes from future climate change, especially where these exceed coping capacity.
- For WP6 project appraisal. There are a number of elements here, though the main focus will be on effects of climate change on ongoing projects (especially infrastructure) and short-term decisions, i.e. climate risk screening and mainstreaming, noting that for Newer Member States, there are existing adaptation deficits. While there will be some consideration of long-term challenges, these are likely to be centred on iterative plans, rather than on short-term term appraisal.
- For WP7 policy appraisal. The key focus is likely to be on mainstreaming, though planning for longer-term challenges will be a component.
- For WP9 Developing countries. This is likely to have a strong focus on addressing the current adaptation deficit – with consideration also of mainstreaming in development plans. For some particular risks (e.g. SLR and small islands) there will be some longer-term elements.

Adaptation Appraisal and Decision Support

A key part of the ECONADAPT policy framework is the appraisal of adaptation options. The appraisal of adaptation is often considered in similar terms to mitigation. However, it is clear that there are major differences between the two, and it is useful to highlight these.

There are widely accepted methods for identifying and prioritising options for reducing greenhouse gas (GHG). As mitigation is concerned with reducing a global burden, it is possible to compare options directly across and between sectors using cost-effectiveness analysis and the metric £/tCO_2. This provides a simple and efficient way to prioritise options and to assess potential benefits/outputs. However, it is much more challenging to identify and prioritise early adaptation for a number of reasons:

- There are no simple common metrics to compare and prioritise adaptation interventions. While mitigation targets a common burden (greenhouse gas emissions, GHG), which can be measured in terms of £/tCO_2 abated, adaptation targets a large number of sector-specific impacts. These vary even with sectoral contexts (e.g. for coastal flooding, there is the flooding of property, coastal erosion, saltwater intrusion and wetland loss). The analysis of impacts and adaptation benefits therefore involves additional steps, e.g. to assess who is exposed? how are they affected by climate? and what impacts arise as a result? Adaptation is thus highly site and context specific.

- Adaptation has to account for the dynamic and changing nature of climate change over time, i.e. the baseline impacts and the levels of adaptation benefits vary. This requires an additional time element as well as the consideration of inter-dependencies.

- There are a set of different challenges (or problems) for adaptation to address, related to current climate variability, near-term mainstreaming, and future climate change. This requires portfolios of options, rather than a single, linear optimised solution (as with mitigation).

- There is high uncertainty associated with future climate change and associated impacts and thus with future adaptation benefits. This uncertainty cannot be ignored with the use of central projections and estimates (as with mitigation). Uncertainty needs to be included in the selection of adaptation options and the decision framework for prioritisation.

- Many of the most important impacts are in non-market sector benefits (e.g. health, ecosystems), or involve indirect pathways (e.g. from an initial flood leading to indirect costs). This makes the quantification and valuation of impacts – and especially the quantification and valuation of adaptation benefits – very difficult.

- Many promising early adaptation options are non-technical in nature, or involve ancillary or qualitative benefits (unlike the technical, quantitative focus of mitigation options). This makes the analysis of outcomes and benefits, and subsequent economic appraisal, much more challenging.

- There is usually a stronger equity dimension, in relation to the distributional impacts of climate change (which has largest relative impact on the poor) and thus there is an issue over the selection of adaptation options to address the most vulnerable.

- There is usually high variability in the baseline counter-factual, for example with annual rainfall variability or probabilistic extreme events (e.g. floods and droughts). This makes it more difficult to assess future impacts and adaptation benefits. It also makes it difficult to monitor and evaluate short-term adaptation outcomes, because it is difficult to attribute adaptation outcomes against this underlying variability. Furthermore, many of the early adaptation steps to address longer-term climate change extend beyond the lifetime normal project monitoring cycles. While process based indicators can be used to address this problem, these are less tangible than outcome based indicators.

- In the LDC context, there is a strong overlap between many adaptation activities and existing development activities. Indeed, adaptation cannot be considered as a stand-alone activity and it needs to be integrated (mainstreamed) with underlying sectoral or development priorities and activities. It also needs to take account of the existing policies in place, with a much greater focus on marginal policy appraisal.

Of these, the greatest challenge is with the incorporation and treatment of uncertainty, particularly for future climate change (longer-term decisions or short-term decisions with long life-times) and this has been a recent focus in the academic and grey literature.

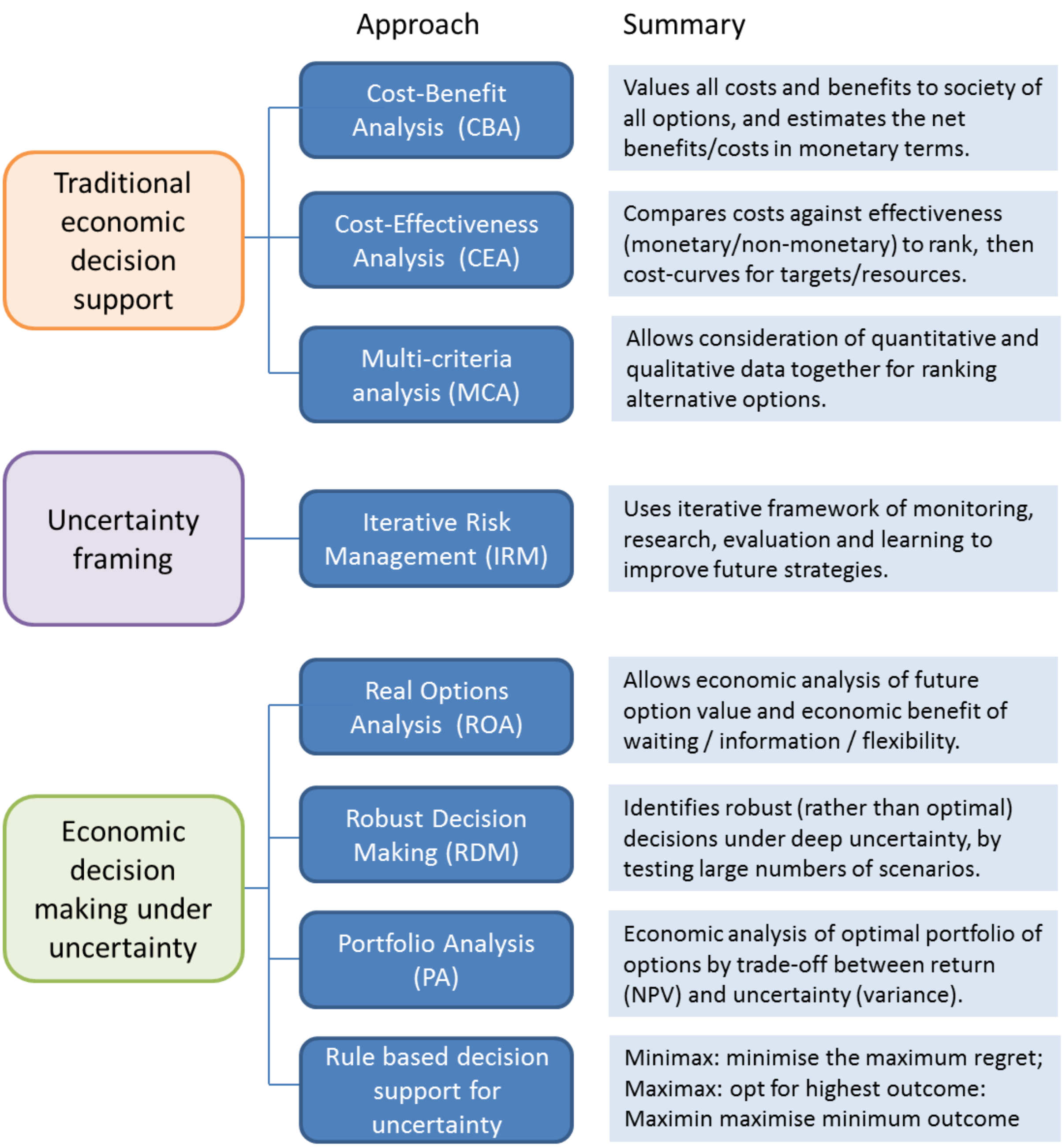
Appraisal and decision making under uncertain

The most common techniques used in project appraisal have limitations in coping with the uncertainty around future climate change. Whilst decision making under uncertainty has become central to the generic adaptation literature, there has been less attention in the economic assessment of adaptation, and the default has been for scenario-based impact assessment and cost-benefit analysis, with little consideration of uncertainty.

However, in the last few years, a number of alternatives have emerged. These include the incorporation of uncertainty within conventional decision support tools for adaptation, i.e. within cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis. It also includes a set of new approaches that explicitly address uncertainty, notably:

- Real option analysis;
- Robust decision making;
- Portfolio analysis;
- Iterative risk management.

A summary of these methods is presented below.



Summary of Adaptation Decision Support and Appraisal Tools

Source Updated from Watkiss et al 2014

Additional information is also available on a range of individual appraisal tools and their application to adaptation on the Mediation common platform, including case study examples http://mediation-project.eu/output/technical-policy-briefing-notes. A review of adaptation applications and case studies has been made. The studies are loaded onto the ECONADAPT project space.

A summary of the approaches and their application to adaptation is included in the Appendix.

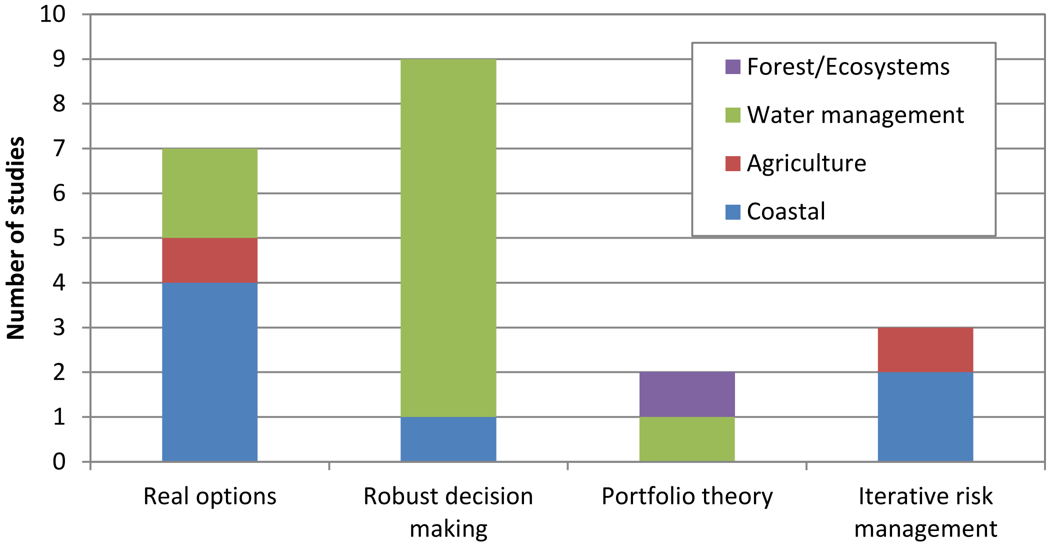
Adaptation Applications and Applicability

A summary of the case study applications by tools and sector is presented below.

Examples of Appraisal Methods in the Adaptation Context

Tool	Published Example Applications
Cost-Benefit Analysis	AIACC (2006). This South African study examined the benefits and costs of avoiding climate change damages through structural and institutional options for increasing water supply in the Berg River Basin in the Western Cape Province. The UBA (2012) project applied cost-benefit analysis to consider 28 adaptation options for Germany.
Cost-Effectiveness Analysis	Boyd et al (2006) undertook a detailed application of cost-effectiveness for water resource zones and the potential adaptation response to address household water deficits in the UK. Tainio et al. (2013) investigated the cost-effectiveness of alternative conservation measures (adaptation options) that could maintain the biodiversity of Finnish semi-natural grasslands under a changing climate.
Multi-criteria analysis	Van Ierland et al. (2007) (De Bruin et al. (2009) applied MCA to assess adaptation options for the Netherlands as part of the Routeplanner national study. This used a qualitative MCA, which included various adaptation criteria. A quantitative MCA was used in the Thames Estuary 2100 project (EA, 2009: 2011) as part of a broader study looking at future coastal flood defences for London. The MCA was used to include qualitative criteria (environment, heritage, etc.) alongside formal economic cost-benefit analysis.
Real Options Analysis	Jeuland and Whittington (2013) applied real option analysis for a water resource planning case study (large water storage projects) in Ethiopia along the Blue Nile. Van der Pol, et al (2013) looked at optimal dike investments under uncertainty with learning about increasing water levels. Linquiti and Vonortas (2012) analysed coastal protection investments and found using real options led to better use of resources in Dhaka and Dar-es-Salaam. Scandizzo (2011) applied ROA to assess the value of hard infrastructure, restoration of mangroves and coastal zone management options in Mexico. Kontogianni et al (2013) used ROA to assess the value of maintaining flexibility (e.g. scaling up or down, deferral, acceleration or abandonment) to engineered structures in Greece. Gersonius et al, 2013 applied to water and flood risk infrastructure in an urban site in the UK, Dobes, 2010 applied to housing design for flooding in Mekong Delta Vietnam and World Bank 2009 applied to agricultural irrigation in Mexico.
Robust Decision Making	A comprehensive, formal application of RDM was undertaken by Lempert and Groves (2010) for Southern California's Riverside County Inland Empire Utilities Agency (IEUA). There is an application of robust decision making for planning coastal resilience for Louisiana (Groves and Sharon, 2013), an application to water scarcity in the Colorado River Basin (Groves et al, 2013) and to flood risk management in Ho Chi Minh City in Vietnam (Lempert et al, 2013). Dessai and Hulme (2007) present an example of the application for RDM to look at climate uncertainty for water supply management in the UK. Nassopoulos et al (2013) applied to dam dimensioning for a small catchment in Greece.
Portfolio Analysis	Crowe and Parker (2008) provide an application of the approach for forests, to investigate genetic material that could be used for the restoration or regeneration of forests under climate change. Hunt (2009) applied portfolio analysis to a case of flood management at the local geographical scale, for river flood risks in the UK, looking at portfolios of hard and soft options
Iterative Risk Assessment	The Thames Estuary 2100 project (EA, 2009: 2011: Reeder and Ranger, 2011) developed a tidal flood-risk management adaptation plan for London using an iterative planning approach and adaptation pathways, with a detailed monitoring and evaluation strategy. In the Netherlands the Delta programme has included consideration of river flooding (Delta Programme, 2008: 2011: 2014) moved to dynamic adaptation pathways. An iterative approach for port development comparing upgradeable versus one off investments was undertaken by the IFC (2011) on the port of Cartagena, Colombia. Watkiss et al (2013) applied an iterative approach to the development of the Climate Resilience Strategy for Agriculture in Ethiopia.

Whilst these tools have primarily been developed in the context of project-level appraisal, in principle they can be used to prioritise policy initiatives at the national and sectoral scale. However, at the national-sector level, these tools serve principally as an organising framework, often with semi-quantitative versions due to data availability, though they provide a good guide to the economic sense of the initiatives. At the project level, where data is available, they can be applied more quantitatively. The main focus has been on sea level rise (which is easier to assess due to its slow-onset nature, and a known direction of change) and water management.



Summary of case studies of new decision support tools for adaptation

An analysis of these studies reveal that most economic applications are hypothetical studies, often focused on technical adaptation, with less applications in direct project or policy appraisals (e.g. for real schemes or sectors). The more applied studies include the application of iterative risk management in national policy appraisal in the Netherlands (iterative management for the Delta Programme, 2014) and Ethiopia (in the National Climate Resilience Strategy: FDRE, 2014), and also at the project level with the application to the London Thames Estuary 2100 project (EA 2009: 2011). It also includes applications of robust-decision making to water management in the Colorado river (Groves et al, 2013), flood risk management in Ho Chi Minh City in Vietnam (Lempert et al, 2013) and planning coastal resilience for Louisiana (Groves and Sharon, 2013). While real-options analysis has been applied in practice in the mitigation domain, the application to adaptation remains theoretical, as is portfolio theory: ROA has also focused on sea level rise, which is easier to assess due to its slow-onset nature, and known direction of change.

Potential applicability: matching tools to relevant adaptation

There are no hard-or-fast rules on which tool to use, however, it is clear that certain tools lend themselves more to specific contexts or sectors. Furthermore, the level of time and resources available, and the size of the investment decisions, will determine the level of detail needed, and also which support tool might be justified.

Some studies (e.g. Ranger et al, 2010) have attempted to provide decision trees to help decision makers select the appropriate tool for quantification. However, these still adopt a primarily theoretical framework. A more pragmatic analysis was presented in Watkiss et al (2014), which summarises the strengths and weaknesses of the tools. The grading of resources and expertise required are relative; most of these tools are resource/expertise-intensive. However, depending on the size of the investments being considered, such resources can be justified by minimising investment resource mis-allocation. A summary is included below. Importantly, none of these tools is universally applicable to all adaptation problems and they each have particular strengths for certain types of decisions and/or applications.

Attributes and Application of Decision Support Methods for Adaptation

Decision-Support Tool	Strengths	Challenges	Applicability	Potential use
Cost-Benefit Analysis	Well known and widely applied.	Valuation of non-market sectors / non-technical options. Uncertainty limited to probabilistic risks / sensitivity testing.	Most useful when climate risk probabilities known and sensitivity small.	To identify low and no regret options (short-term) in market sectors. As a decision support tool within ICRM
Cost-Effectiveness Analysis	Analysis of benefits in non-monetary terms.	Single headline metric difficult to identify and less suitable for complex or cross-sectoral risks. Low consideration of uncertainty	As above, but for non-monetary sectors (e.g. ecosystems) and where social objective (e.g. acceptable risks of flooding).	As above, but for market and non-market sectors.
Multi-Criteria Analysis	Analysis of costs and benefits in non-monetary terms.	Relies on expert judgement or stakeholders, and is often subjective, including analysis of uncertainty.	Where mix of quantitative and qualitative data. Can include uncertainty performance as a criteria	As above, but also use for scoping options (policy level). Can complement other tools and capture qualitative aspects.
Iterative Risk Assessment Frameworks	Iterative analysis, monitoring, evaluation and learning.	Challenging when multiple risks acting together and thresholds are not always easy to identify.	Useful where long-term and uncertain challenges, especially when clear risk thresholds.	For appraisal over medium-long-term. Also applicable as a framework at policy level.
Real Options Analysis	Value of flexibility, information.	Requires economic valuation (see CBA), probabilities and clear decision points. .	Large irreversible decisions, where information on climate risk probabilities.	Economic analysis of major capital investment decisions. Analysis of flexibility within major projects.
Robust Decision Making	Robustness rather than optimisation.	High computational analysis (formal) and large number of runs.	When large uncertainty. Can use a mix of quantitative and qualitative information.	Identifying low and no regret options and robust decisions for investments with long life-times.
Portfolio Analysis	Analysis of portfolios rather than individual options	Requires economic data and probabilities. Issues of inter-dependence.	When number of complementary adaptation actions and good information.	Project based analysis of future combinations. Designing portfolio mixes as part of iterative pathways.

Adapted from Watkiss et al, 2014.

Policy-level assessments are more likely to make use of the established tools that provide a framework for more aggregated analysis, although iterative risk frameworks and robust decision making also have high potential for programme/sector analysis (though they are more proven at the project level). At the project scale, tool selection will be influenced by data availability and the level of uncertainty. Several of more economic focused approaches (real options and portfolio theory) require probabilistic inputs, which is challenging for future climate projections, and they also require quantitative inputs.

The application or adaptation problem also determines the suitability of the decision tool. For example, for analysis that is focused on current climate variability (the adaptation deficit), existing decision support tools can be used, including CBA. However, as adaptation interventions are often in areas that are difficult for valuation, and usually involve a lack of quantitative information, then multi-attribute analysis (or multi-criteria analysis) is often used. For the analysis of short-term decisions with long life-times and longer-term challenges, a greater focus on new decision support tools is warranted. RDM has broad application for current and future time periods. When investments are nearer term (especially high upfront capital irreversible investments), and where there is an existing adaptation deficit, ROA is a potentially useful tool, whereas for long-term applications in conditions of a low current adaptation deficit, IRM may be more applicable. Importantly while the tools are presented individually, they are not mutually exclusive.

It is worth noting that the differences between the tools are not limited to data and capacity constraints but may have a material impact on the order of prioritisation of adaptation options. Klijn et. al. (2014) demonstrate that applying RDM results in a different order from CBA, and CBA produces a different order from CEA.

Light Touch Approaches

A critical finding of the review and cases studies is that all of these methods are resource intensive and technically complex, and this is likely to constrain their formal application to large investment decisions or major risks.

Given this, a critical question is whether their concepts can be used in 'light-touch' approaches that capture their conceptual aspects, while maintaining a degree of economic rigour. This would allow a wider application in qualitative or semi-quantitative analysis. This could include the broad use of decision tree structures from ROA, the concepts of robustness testing from RDM, the shift towards portfolios of options from PA, and the focus on evaluation and learning from IRM for long-term strategies.

There is already some early progress advancing these types of light-touch applications, e.g. Hallegatte et al. (2012); Ranger et al (2013) [DFID Topic Guidance on Uncertainty].

However, as yet, there is nothing that seems suitable in balancing the trade-off between quantitative analysis and pragmatic application. Furthermore, recent analysis in Rwanda as part of the ECONADAPT project (WP9), reveals that both governments and development partners are likely to struggle even with relatively simple uncertainty analysis (unless they have external assistance). This may mean a greater focus on simple quantitative sensitivity testing, coupled with some qualitative consideration of uncertainty, is the most pragmatic way forward for these less resource intensive applications.

Application to the work packages

In terms of the potential for different decision tools for the policy case studies.

- WP5 Disaster Risk. This is likely to have a strong focus on addressing the economic risk based CBA for the adaptation deficit – though the extension to include capacity building and non-market sectors is highlighted, which may lead to consideration of MCA and CEA.   There is also some relevance for longer-term iterative economic appraisal.

- WP6 project appraisal. The main focus is likely to be on decision support to capture future climate change, i.e. RDM, ROA and possibly PA.
- WP7 policy appraisal. The key focus is likely to be on iterative adaptive management, though with consideration of other tools for more specific options.
- WP9 Developing countries. This is likely to have a strong focus on addressing the economic risk based CBA for the adaptation deficit – though the extension to include capacity building and non-market sectors is highlighted, which may lead to consideration of MCA and CEA.   There is also some relevance for longer-term iterative economic appraisal.

Policy Review

Adaptation European/National Policy Review

The final part of the review has been to focus on existing International, European and national policy, including policy and project appraisal guidance for adaptation. This provides some of the socio-institutional context for applying the policy-led ECONADAPT framework and provides possible entry points for the case studies.

European Adaptation Policy and the EU 2013 Adaptation Strategy

The Commission began developing a specific EU adaptation policy response in 2005, with the founding of a dedicated working group of the ECCP II, leading to a Green Paper (CEC, 2007). This was followed by a White Paper (CEC, 2009). In 2013, the EU published an EU Strategy on adaptation to climate change (EC, 2013a) with a supporting impact assessment (EC, 2013b, c, d). The details and supporting annexes are summarised in the appendix.

EU 2013 Adaptation Strategy

The overall aim of the EU Adaptation Strategy is to *contribute to a more climate-resilient Europe. This means enhancing the preparedness and capacity to respond to the impacts of climate change at local, regional, national and EU levels, developing a coherent approach and improving coordination*.

It also set out relevant issues in relation to:

- **Uncertainty**. *Uncertainty regarding the trajectory of greenhouse-gas emissions, future impacts of climate change and related adaptation needs remains a challenge for policy making in this area. Yet, uncertainty cannot be seen as a reason for inaction. It notably calls for a strong emphasis on incorporating win-win, low-cost and no-regret adaptation options. These include sustainable water management and early warning systems. Ecosystem-based approaches are usually cost-effective under different scenarios. They are easily accessible and provide multiple benefits, such as reduced flood risk, less soil erosion, improved water and air quality and reduced heat-island effect*.
- **DRM linkages**. *Adaptation action is closely related and should be implemented in synergy and full coordination with the disaster risk management policies that the EU and the Member States are developing*.
- **Growth, jobs and competiveness**. Adapta*tion action will bring new market opportunities and jobs, in such sectors as agricultural technologies, ecosystem management, construction, water management and insurance. European companies, including SMEs, can be early first movers in developing climate-resilient products and services and grasp business opportunities worldwide. In line with the Europe 2020 Strategy, the Adaptation Strategy will help the EU move towards a low-carbon and climate-resilient economy, and will promote sustainable growth, stimulate climate-resilient investment and create new jobs*.

The Strategy identifies three themes:

- Promoting action by Member States
- Better informed decision-making

- Climate-proofing EU action: promoting adaptation in key vulnerable sectors

and identified eight actions:

- Encourage all Member States to adopt comprehensive adaptation strategies;
- Provide LIFE funding to support capacity building and step up adaptation action (2013-2020);
- Introduce adaptation in the Covenant of Mayors framework (2013/2014);
- Bridge the knowledge gap;
- Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe;
- Facilitate the climate-proofing of the Common Agricultural Policy (CAP), the Cohesion Policy and the Common Fisheries Policy (CFP);
- Ensuring more resilient infrastructure;
- Promote insurance and other financial products for resilient investment and business decisions.

These are detailed in the Appendix.

The most critical relates to the need for Better informed decision-making (to bridge the knowledge cap). The Strategy highlights that substantial knowledge gaps need to be filled and that a solid knowledge base is also essential to drive innovation forward and support the market deployment of innovative climate adaptation technologies. Two actions are identified, one of which is information on damage and adaptation costs and benefits. This provides a key opportunity for enhancing the impact of the ECONADAPT project.

A further relevant area is for Climate-proofing EU action: promoting adaptation in key vulnerable sectors. These initiatives are extremely important for a number of case study domains in ECONADAPT, including DRR (WP6), project appraisal (WP7) and especially policy appraisal (WP8). The strategy outlines that these moves to mainstream climate change adaptation into EU policies will be pursued in priority fields such as energy and transport.

The strategy highlights that infrastructure projects, which are characterised by a long life span and high costs, need to withstand the current and future impacts of climate change. Building on the recent mandate to assess the climate change implications for Eurocodes, and the Commission's work with standardisation organisations, financial institutions and project managers needs to analyse to what extent standards, technical specifications, codes and safety provisions for physical infrastructure should be strengthened to cope with extreme events and other climate impacts.

Finally, the Strategy outlines that disaster insurance has a generally low market penetration rate at the moment in Member States. Discussions should take place with stakeholders on the basis of the Green Paper on the insurance against natural and man-made disasters. This latter area has high relevance for WP5.

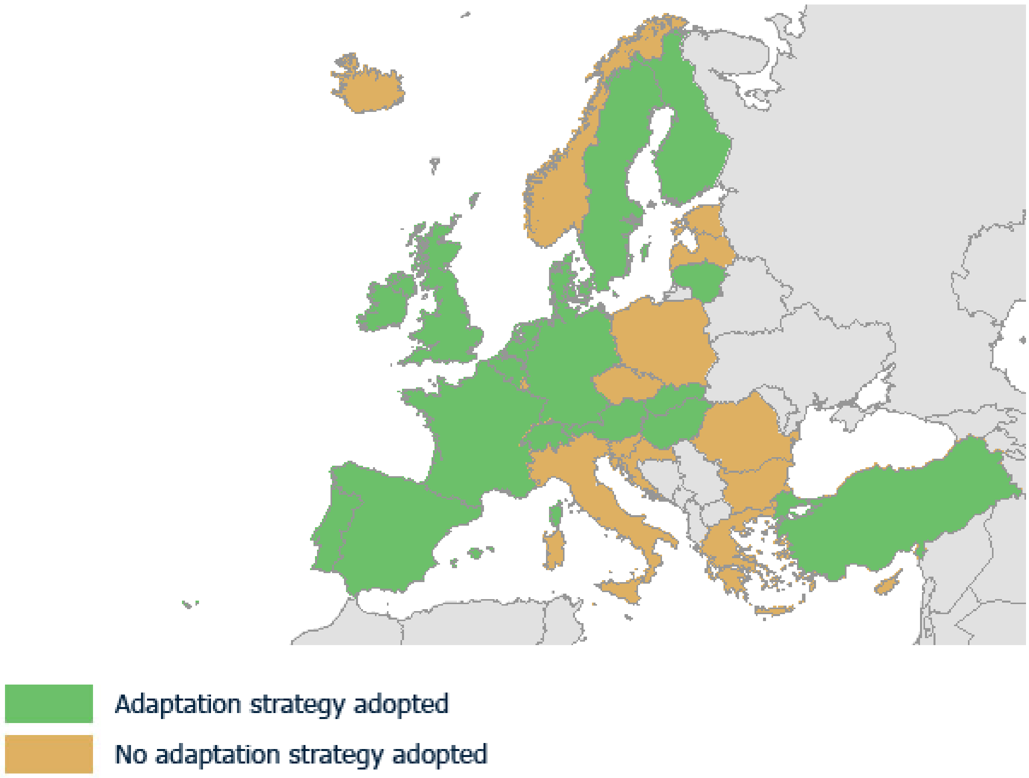
In terms of financing, the Strategy highlights that improved access to funding will be a critical factor in building a climate-resilient Europe. The draft 2014-2020 Multi-annual Financial Framework (MFF) includes a proposal for increasing climate-related expenditure (for mitigation and adaptation) to at least 20 % of the EU budget. It is strategically important for such investment to be climate-resilient. Specifically, the Commission has included climate change adaptation in its proposals for all relevant EU finance programmes for 2014-2020. Moreover, several EU funds and international financing institutions, such as the European Investment Bank and the European Bank for Reconstruction and Development, also support adaptation measures. The Commission will explore further ways of accommodating some adaptation investment expenditure, such as expenditure co-financed by the

EU in the assessment of Stability and Convergence Programmes. This implies a very large increase in relevant adaptation flows.

Additional aspects of the Strategy are included in the Appendix.

Member State Adaptation Strategies and Mainstreaming

The Climate-Adapt site provides information on which countries currently have an adaptation strategy adopted.



Source Climate-Adapt (http://climate-adapt.eea.europa.eu/countries/) (April, 2014).

As highlighted in the earlier discussion, most of these are impact focused and science first approaches. It highlighted the Dutch and UK plans as the most advanced. These provide some useful information of relevance for the ECONADAPT project, because they have also adopted iterative risk frameworks, as recommended in the policy framework.

The Deltacommissie 2008 (Working together with water) has the mandate to create the vision on the long-term protection of the coast and its hinterland. It developed an integrated vision for the future extending to 2100 and beyond, including the costs of delivering this vision. This considered flood protection, but also includes fresh water supplies, and the wider interactions between life and work, agriculture, nature, recreation, landscape, infrastructure and energy, with a strong emphasis on sustainability. This programme considers an iterative adaptive management approach that prepares for the future and considers decisions in a timely fashion to plan investments (Delta Programme, 2011). It also considers short-term measures that increase adaptability (flexibility) and resistance to extreme events (robustness), to make it possible to delay reaching tipping points. Most recently, the development of adaptation plans have also been extended to consider dynamic adaptation pathways (Delta Programme, 2014; Haasnoot et al., 2013). The Netherlands has also produced a comprehensive tool for dealing with climate adaptation issues ('handreiking ruimtelijke adaptatie').

In the UK, the government's approach is for climate change adaptation to be mainstreamed across all policy areas. To facilitate this process, the first UK climate change risk assessment, published in 2012, was followed up with a detailed analysis of adaptation, as part of the Economics of Climate Resilience study and the National Adaptation Programme (Frontier, 2013; HMG, 2013; Defra, 2012). The adaptation method for this (Watkiss and Hunt, 2011) used iterative adaptive management, drawing on the project level example of the Thames Estuary 2100 project, which developed a medium-long term plan for London to future sea level rise using iterative frameworks (EA, 2009: 2011). The national plan focused on mainstreaming at the sector level, working with the individual departments across government. The analysis undertook a pathway analysis for a number of key risks to identify entry points and activities within existing policies and areas. The UK has also invested heavily in capacity support and in the development of tools, initially with the UK Climate Impacts Programme, and more recently with the Climate Ready team at the Environment Agency, to provide support to other policy areas for the mainstreaming approach. The UK is also notable as it has produced specific economic supplementary guidance for adaptation (HMT, 2009) and has a legal mandatory framework for adaptation. I

Mainstreaming

Adaptation mainstreaming is the integration of adaptation into decision-making across a range of policy areas, rather than through the implementation of standalone adaptation measures. Mainstreaming adaptation into policy-making is a continuing process, requiring the integration into existing policy and project cycles. A key element of this is the integration of climate risks into the decision-support tools that are used in standard policy and project appraisal.

Mainstreaming is important because policy measures that will affect adaptation are often implemented for non-climate reasons, with multiple objectives and ancillary costs and benefits that are material to the overall choice of the measures. It is therefore important to understand the context for an intervention and decision, including the existing policy and objectives, non-climatic drivers, and the current decision-making process. As an example, resilience may be mainstreamed as part of an urban regeneration programme, but the design of such a programme will be dominated by local economic development objectives and other drivers, such as demographic and land-use change. Such a mainstreaming practice will also require a good understanding of the individual organisations, institutional networks and processes making relevant decisions. Critically, all of these will differ with each specific adaptation problem. In this regard, adaptation is very different to mitigation (Watkiss, Benzie and Klein, 2015) and this is due to the strong overlap between adaptation and existing activities that address current climate resilience (e.g. disaster risk reduction, water management, etc.).

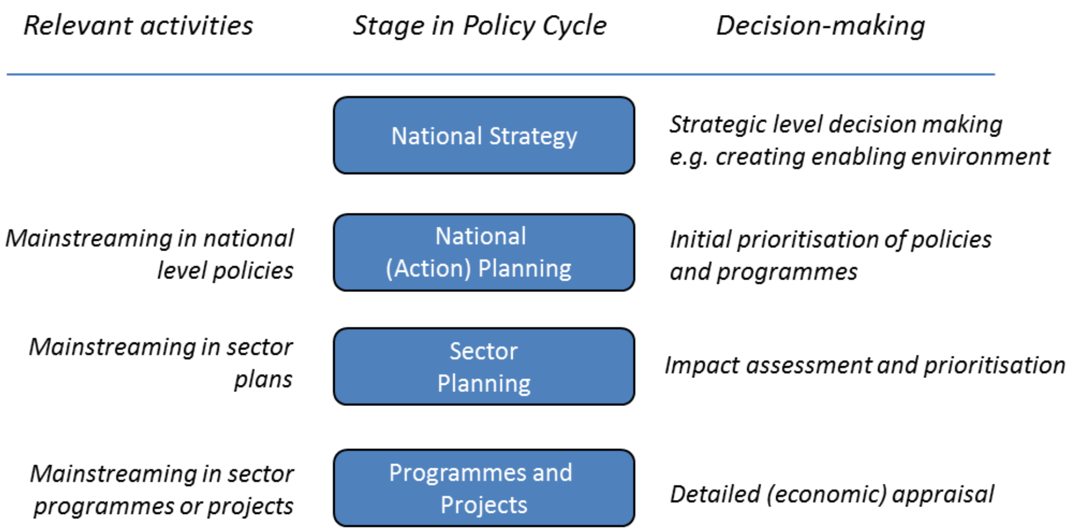
A key issue here relates to relevant entry points (OECD, 2009; UNDP-UNEP, 2012), i.e. the opportunities in the national, sector or project planning process where climate risk considerations can best be integrated.

At the national level, strategic decisions are taken that create the enabling environments for public- and private-sector actors, as well as communities and individuals. In the climate change context, there are now a large number of national OECD climate change strategies and an emerging number of national adaptation action plans (see Mullan et al., 2011: Wilby, 2012; EEA, 2014). However, relatively few of these plans have integrated adaptation. The best examples in Europe are found in the UK and the Netherlands, detailed above.

At the programme to project level, existing safeguard mechanisms, such as environmental impact assessment (EIA), provide a natural entry-point for considering whether projects are vulnerable to climate change or could exacerbate climate risks elsewhere. Although originally designed to prevent negative impacts on the environment, the EIA process has the benefit of being a familiar and well-established part of the policy-making process in OECD countries (Agrawala et al., 2010). It will, however, only capture those policies that are subject to environmental impact assessments, such as infrastructure construction. Moreover, it may require revision of the legal framework to include climate risks.

A complement to the identification of high-risk policies, projects and programmes is the integration of adaptation into existing policy and project appraisal guidance. This entails the modification of existing appraisal guidance to also cover climate change or to support the consideration of some of the additional aspects and challenges of adaptation. For example, in the UK, supplementary “Green Book” guidance was published to support policy makers in accounting for adaptation in economic policy appraisal.

Mainstreaming steps and entry points



A number of lessons have also been compiled on mainstreaming

• Mainstreaming will need to align to the policy and institutional landscape, and consider existing processes or guidance, such as project cycle steps and appraisal documentation already in place.

• Pragmatism is essential as any tool or guidance need to fit with the resource, time, capacity and expertise available for policy or project analysts; otherwise they will not get used.

• The stage at the decision-making process when adaptation is considered is critical. It is important to ensure that the mainstreaming activities come early enough in the process to influence the decision, or are targeted at key ‘windows of opportunity’ (Ballard, 2014; Moser and Ekstrom,

2010) which will often be non-climatic in nature (e.g. replacement or maintenance cycles). This may require strategic issues to be picked up early-on, either in relation to the sector strategy or the overall investment portfolio (e.g. at river basin level rather than project level). It also means that climate risks and mainstreaming activities needs to occur early in the project cycle, at the concept or design stage, and ideally be aligned to approval milestones. The inclusion of adaptation considerations at the environmental impact assessment stage, for example, is usually too late to have a major influence on project design.

- It may be useful for decision-makers to also identify opportunities that can be created by implementing adaptation, rather than focusing only on the risks and amelioration actions (Hallegatte, 2011).

- The path from identifying potential entry points and providing tools through to implementation is challenging. Achieving this requires involving a diversity of users and stakeholders, finding relevant champions, building partnerships and providing support networks and capacity building.

International Assistance and Least Developed Countries

Work package 9 of ECONADAPT focuses on overseas development assistance for adaptation. The policy context and entry points for this are outlined below.

The EU 2013 Adaptation Strategy does mention the international aspects of climate change.

The strategy takes account of global climate change impacts, such as disruptions to supply chains or impaired access to raw materials, energy and food supplies, and their repercussions on the EU. The EU's dialogue and cooperation with neighbouring countries and developing countries on adaptation issues is channelled through the Enlargement and European Neighbourhood policies and EU development cooperation policy.

It is also clear that given the Copenhagen pledges, there will be large scale financing of adaptation from Europe via development assistance, from the EC (DG DEVCO – Development and Cooperation - EUROPEAID) and Member States, through multi-lateral and bi-lateral initiatives and international finance institutes. Several Member States having set up large (earmarked) resources for climate change financing, as an example, the UK has set aside a £2.9 billion budget for fast track mitigation and adaptation finance (the ICF, International Climate Fund). This support aligns with the existing UNFCCC process and for adaptation; this is focused on the **Least Developed Countries (LDCs).** There are 50 countries defined as Least Developed Countries by the UN[5].

National Adaptation Plans)

The primary current policy focus in LDCs – as part of the UNFCCC process - is around the development of **National Adaptation Plans (NAPS).** The national adaptation plan (NAP) process was established under the Cancun Adaptation Framework (CAF). It enables Parties to formulate and implement national adaptation plans (NAPs) as a means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those

[5] for a list, see http://unfccc.int/cooperation_and_support/ldc/items/3097.ph

needs. It is a continuous, progressive and iterative process which follows a country-driven, gender-sensitive, participatory and fully transparent approach (UNFCCC[6]).

Through decision 1/CP.16, the Conference of the Parties (COP) has established the NAP process for least developed country (LDC) Parties. Under it, LDC Parties are invited to identify their medium- and long-term adaptation needs and develop and implement strategies and programmes to address these needs, building upon their experience in preparing and implementing national adaptation programmes of action (NAPAs).

The NAPs represent a major extension beyond the NAPAs, the latter being associated with a process for the LDCs to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change - those needs for which further delay could increase vulnerability or lead to increased costs at a later stage (UNFCCC[7]). The NAPAs have focused on the use of vulnerability assessment, and are project based and small-scale, with most countries listing a priority list of projects that total around £10 million (see the NAPA priority database[8]).

There are overview and technical guidelines for the NAP process, prepared by the Least Developed Countries Expert Group (LEG), and based on the initial guidelines adopted at COP18[9]. The agreed objectives of the national adaptation plan process are (LDC expert group, 2012a, b):

(a) To reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience;

(b) To facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

The guidance is framed around a cycle of adaptation that is similar to the PROVIA outline above. The NAP process and the technical guidance (LEC, 2012) is based around four steps.

- A. Lay the groundwork and address gaps. This step involves stocktaking on available information and addressing capacity gaps, as well as understanding needs.
- B. Preparatory elements. This step centres on the analysis of current and future climate change scenarios and vulnerabilities, as well as identification, review and appraisal of adaptation options at various aggregation levels. It also involves integrating climate change into national and sectoral planning.
- C. Implementation Strategies. This step in involves prioritisation of climate change adaptation in national planning, and development of long-term national adaptation implementation strategy. It also includes enhancing capacity.
- D. Reporting, monitoring and review.

Of particular relevance to ECONADAPT are steps B3 and C1 (LDC EG, 2012a):

[6] http://unfccc.int/adaptation/workstreams/national_adaptation_plans/items/6057.php
[7] http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7567.php
[8] http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4583.php
[9] http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7279.php

Step	Key Questions	Indicative activities
B3 Reviewing adaptation options	• What are the costs and benefits of each adaptation option? • How best can the adaptation options be implemented, and what are the conditions for success? • Is it possible to identify co-benefits between the adaptation options and development?	a. Appraise individual adaptation options, including economic, ecosystem and social costs and benefits, and possibilities for unintended (positive and negative) impacts of adaptation measures
C1 Prioritising climate change adaptation in national planning	• How can adaptation work best be prioritized for implementation at the national level considering development needs, climate vulnerabilities and risks as well as existing plans? • What criteria can be used to define priority actions?	a. Define national criteria for prioritizing implementation based, inter alia, on: development needs, climate vulnerability and risk and existing plans b. Identify opportunities for building on and complementing existing adaptation activities

Mainstreaming in Developing Countries

In a developing country context, mainstreaming activities usually follow a slightly different path than in developed countries, with different entry points, reflecting the differences in national strategic planning. Many developing countries are producing National Adaptation Plans (NAP). The UN guidance for the development of NAPs outlines the need for mainstreaming in developing such plans - critical because of the strong overlap with existing development activities (LDC Expert Group, 2012a; 2012b). In this context, there are a different set of entry points for mainstreaming, outlined in the table below (UNEP, 2011) that often operate through different organisational leads. This structure closely parallels that outlined for environmental mainstreaming more generally (OECD, 2012).

In the climate change context, there has been progress in recent years, though countries have adopted a range of approaches to mainstreaming adaptation in national development strategies.

Possible entry points for mainstreaming in national strategic planning policy in developing countries

Planning level	Entry point
National government and cross sector ministries	• National development vision (long-term) • Poverty reduction strategy • National development plan (e.g. 5 year) • National budget allocation process or review
Sector ministries	• Sector development plans • Sector master plans • Sector budgets
Subnational authorities	• Decentralisation plans • District plans • Subnational budgets

Source: UNDP/UNEP (2011)

For example, countries already include “environment” as a cross-cutting theme in their national development vision, national development plans (e.g. medium-term plans, five year plans or poverty reduction strategies), and sector development plans. In a few countries, these activities are being integrated, or at least tracked, in the national budget allocation process and in sector budget activities. Such initiatives can be extended to include climate. An example is the Government of Rwanda, which has integrated climate change (with environment) as one of seven cross-cutting issues in national development and sector development planning (Republic of Rwanda, 2014). Further, Rwanda is including related indicators in the budgeting process and public financial management.

Moving to the programme to project level, again there is the potential for using environment or other safeguard systems. For example, climate risk screening can be applied as a step in the policy-making process to identify where policies, programmes or projects may be particularly vulnerable to climate change. This has emerged strongly in relation to investment projects funded by the international finance institutions and multilateral development banks. For example, the African Development Bank (AfDB, 2011) has introduced a Climate Safeguard System that includes a traffic light system or scorecard to identify which projects may be highly vulnerable to climate risk and require a more detailed evaluation to consider integration of climate aspects into design and implementation. These tend to have a strong focus on enhancing the climate resilience of infrastructure or major investments.

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Appendices

Definitions

Definitions continue to advance rapidly in the climate change literature. A number of key definitions are presented below, taken from the IPCC 5th Assessment Report WGII Glossary (Agard and Schipper (2014).

Adaptation. The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Incremental adaptation Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

Autonomous adaptation Adaptation in response to experienced climate and its effects, without planning explicitly or consciously focused on addressing climate change. Also referred to as spontaneous adaptation.

Adaptation assessment. The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.

Adaptation deficit. The gap between the current state of a system and a state that minimizes adverse impacts from existing climate conditions and variability

Capacity building. The practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society, or organization to respond to change.

Co-benefits. The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices. Co-benefits are also called ancillary benefits.

Disaster risk management (DRM). Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development.

Disaster risk reduction (DRR). Denotes both a policy goal or objective, and the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard, or vulnerability; and improving resilience.

Exposure. The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.

Hazard. The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. In the IPCC, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Maladaptive actions (or maladaptation). Actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future.

Resilience. The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Arctic Council, 2013).

Risk. The potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the consequences if these events occur. The IPCC assesses climate-related risks.

Sensitivity. The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Transformation. A change in the fundamental attributes of a system, often based on altered paradigms, goals, or values. Transformations can occur in technological or biological systems, financial structures, and regulatory, legislative, or administrative regimes.

Uncertainty. A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Vulnerability. The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. See also Contextual vulnerability and Outcome vulnerability.

Details of the ECONADAPT framework and types of adaptation

The overall framing of adaptation above outlined the focus now on starting with current climate variability and extreme events (the adaptation deficit), then looking to future climate change considering uncertainty. This leads to three types of general interventions:

1. Current actions that are focused on addressing existing current risks, but which also build resilience for the future. This includes a focus on no- and low-regret adaptation options, as well as capacity building.

2. Analysis of the risks and adaptation for current (short-term) policy or investments that will be exposed to climate change in the future. This includes risk screening of infrastructure and mainstreaming risks into development policy.

3. Planning future actions to address future climate change, working under a framework of decision making under uncertainty. This includes a focus on iterative planning.

Recent work (Watkiss et al, 2014[10]) has sought to separate these into a more explicit **typology** (a classification of adaptation), focusing particularly on **early activities**, consistent with the focus in ECONADAPT. This is shown in the Figure below. It is stressed that these activities are complementary and not a linear sequence, though there is a general time dimension from top to bottom. This provides a way to structure options, and to then examine the economic methods and information to help in their analysis.

Each of the three broad areas reflects different risks, involves different timing, and has varying characteristics. They also have different information needs (inputs): those towards the top will require information on current variability while those towards the bottom information on uncertainty. Finally, there are differences in the modality through which these actions might be considered, e.g. whether through existing development policy or stand-alone adaptation programmes.

[10] This section draws on recent analysis for the UK Department for International Development on the potential for low and no-regret adaptation (Watkiss et al, 2014), which has co-funded part of the ECONADPT project.

EARLY ADAPTATION	Type of early adaptation	Description	Information needs	Examples
1. Low/no regret options to address deficit	a) Good Practice	Options that are beneficial to do now. Often no-regret, but not climate specific.	Baseline implementation status	Efficiency improvements Farm level productivity
	b) Addressing current climate vulnerability	Options that reduce current climate risks, and build resilience for the future.	Current vulnerability & hazard data	Disaster risk reduction. Soil and water conservation.
	c) Capacity Building	Supporting actions to deliver enabling environment for adaptation.	Baseline and institutional information	Improved climate services (forecasts) Awareness raising. Institutional strengthening.
2. Risk screening, resilience & mainstreaming	a) Low cost, robust and flexible options	Risk screening and mainstreaming climate into plans or investment for future resilience	Future climate risks and uncertainty	Low-cost over-design Upgradeable infrastructure Flexible design
	b) Capacity and information	Information to reduce risks. Capacity building and research to build information and evidence	Baseline information and uncertainty	Risk mapping Siting/land-use plans to avoid future risks. Research and pilots
3. Addressing future climate challenges	a) Iterative adaptation pathways	New interventions for new challenges – information and early action for future decisions	Future climate Thresholds and uncertainty	Iterative plans, with research and monitoring programmes
	b) Trans-formative change	Structural, systemic or societal change recognising limits of adaptation	Societal futures, thresholds, uncertainty	Structural economic change. Population relocation.

Typology of Adaptation Interventions for Iterative Climate Risk Management

Source Watkiss et al, 2014.

The types of interventions also vary in nature with the type of action.

For those options that address the current adaptation deficit (1), a differentiation is made between options that have a strong overlap with current development (*good development*), which may be more appropriate for implementation through existing country programmes, and options that directly address climate variability (*addressing climate variability*). Both these are associated with concrete early actions (e.g. technical implementation, major investment, scale-up and roll out of promising options, etc.).

Alongside this, there is also a separate category of *capacity building*, reflecting the need for non-technical options to help deliver adaptation. Importantly many of these are qualitative in nature, and have different characteristics to more outcome based options (above). However, they provide the enabling environment to deliver other options and are thus critical for implementation success.

For those options that focus on <u>mainstreaming and resilience (2),</u> a differentiation is made between resilience building (building resilience into infrastructure or development) using *low-cost options, robustness and flexibility* and *information and capacity*. The former is primarily associated with looking to make current investments more resilient, while also noting the trade-off between early action (and costs) and longer-term benefits. The latter is focused around building and using information to reduce future exposure or impacts, e.g. with risk mapping and screening.

Finally, for those options that address the <u>future climate challenges (3),</u> a differentiation is made between the *iterative adaptation pathways*, which build adaptation responses with learning, and *transformative adaptation*, which involves major structural or societal changes.

It is stressed that while 'good development' options (at the top) are not really adaptation, they are often included, especially in the LDC context, e.g. in National Adaptation Plans. Similarly, while transformative/transformational adaptation (at the bottom) is not associated with concrete early actions, there may be a need to start developing the transformative vision for societies/economies today, if there are potential limits to adaptation in the long-term.

Following from the different characteristics and applications, the different types of early options have different types of (economic) **benefits**. These are mapped out in the figure below.

The second column (the type of benefits) highlights the nature of the benefits of each option. This provides the justification for its inclusion.

Those at the top tend to have more outcome-based outputs, which are more quantitative in nature. These can deliver immediate economic benefits (today) as well as building resilience for the future. In contrast, capacity building and information provide non-technical benefits, which are often qualitative in nature, and are thus more process based. However, these still deliver benefits (in economic terms) through the value of information.

The final column highlights that the timing of the benefits also varies. Those at the top lead to more immediate benefits and outcomes. Those at the bottom are more focused on the future, necessitating consideration of discounted benefits and uncertainty.

These differences are important when considering how to assess the options in subsequent appraisal, e.g. in the expected results and for subsequent monitoring and evaluation frameworks. The final column provides a summary of how benefits can be assessed and the potential tools involved. As an example, those options addressing existing climate variability will focus more on the current vulnerability and risk assessment. In contrast, the development of longer-term responses will consider future climate change and uncertainty, and aspects such as robustness or flexibility which require additional attributes to a conventional CBA.

EARLY ADAPTATION	Type of early adaptation	Type of Benefits	Timing of benefits	Analysis of benefits
1. Low/no regret options to address deficit	a) Good Practice	Productivity Efficiency Outcome-based	Now	Classic benefit to cost ratio
	b) Addressing current climate vulnerability	Reducing current climate impacts of variability	Now + potential for future resilience to CC	Benefit to cost ratio but requires climate information
	c) Capacity Building	Value of information Enabling environment Process-based	Some benefits now + better adaptation in future	Less outcome based often qualitative Value of information
2. Risk screening, resilience & mainstreaming	a) Low cost, robust and flexible options	Protect investment Reduced risk Robustness/flexibility	Some now, but mostly future Resilience	Requires future climate information (envelope/range)
	b) Capacity and information	Value of information Enabling environment Process-based	Some now, but mostly future Resilience	Less outcome based often qualitative Value of information
3. Addressing future climate challenges	a) Iterative adaptation pathways	Learning, value of information, option value, avoided lock-in	Future. Action to improve future decisions	Qualitative narratives or more complex iterative appraisal
	b) Trans-formative change	Avoiding major irreversibility, major lock-in, option values	Future. Action now to avoid/adjust to major changes	Futures analysis

Benefits of Types of Adaptation

Source Watkiss et al, 2014

Some additional discussion of the categories is included below.

1) Addressing current climate variability and building resilience

This category is the primary area of focus for early no- and low-regrets adaptation action (see box). It is focused on addressing the impacts and economic costs of current climate variability and extreme events, i.e. on reducing the current adaptation deficit.

Low- and no-regret adaptation

Low- and no-regret adaptation options are now seen as an early priority for adaptation finance, for example, the IPCC SREX report highlights that low-regret; actions are a starting point for adaptation, as they have the potential to offer benefits now and lay the foundation for addressing projected changes. However, there are differences in the literature on exactly what constitutes no – and low-regret adaptation, as outlined in the box.

While the definition of a no-regret option is generally agreed, there are large differences in what constitutes low-regret adaptation – notably on the type of options, the benefits, and their timing. However, it is clear is that there are a set of early adaptation options which are extremely promising for early implementation, i.e. that are likely to be the focus for the adaptation case studies in ECONADAPT.

What are no-regret options?

The concept of no-regret options has been advanced for mitigation, where it relates to measures which can reduce GHG emissions and save costs (i.e. that generate a positive net present value) such as energy efficiency. A similar concept has emerged for adaptation. In this case, **no-regret adaptation** is defined (by the IPCC [2007]) as adaptation policies, plans or options that*:*

'generate net social and/or economic benefits irrespective of whether or not anthropogenic climate change occurs'.

These no regret options provide immediate economic benefits, and they are therefore an obvious area of early adaptation, though they often overlap with development. They also have the potential to build the foundation for adaptation to future climate change. A variation of no-regret options are **win-win** options. While there is no formal definition, these are options with wider social, environmental or ancillary benefits.

What are low-regret options?

There is no agreed definition of low-regret options. A number of definitions have been proposed:

- Options or interventions that are no-regret in nature, but have opportunity, policy or transaction costs. As an example, some climate smart options for agriculture are no-regret in theory, but involve opportunity costs, meaning in practice they are low-regret.
- Options that are probably worth doing in the current climate, and also have benefits in addressing climate change in the future. This often includes low cost options that have benefits that are difficult to monetise (e.g. capacity building, better climate information, etc.). It can also include options that are low cost and provide future information to enable better decisions in the future.
- Options or interventions where the costs are low and the future benefits are high, i.e. low cost measures that can provide high benefits if future climate change emerges (noting the benefits are in the future, rather than immediate).
- Options that are robust or flexible, and thus address uncertainty. This can include options that are robust, i.e. that perform well across many different climate futures (addressing uncertainty), rather than a measure that performs optimally to one defined central future (and poorly to others). It also includes options that are flexible, i.e. that allow changes in plans or project design over time, to take account of new knowledge.

A number of additional points are also highlighted.

- A number of options that are considered low-regret in some studies are considered high-regret in others. This often applies to technical/structural (hard) options. This can be explained by the framing of studies, i.e. whether future climate change uncertainty is considered or not.

- Many no- and low-regret options are non-technical (soft) in nature. This can make their appraisal more challenging, and these soft measures may not always be a substitute for hard adaptation.

- A number of studies highlight the potential for community-based adaptation as a no-regret option, as practical adaptation at the community level seeks win-win outcomes – that benefit both local communities and the ecosystems on which they depend. This involves a different orientation to a standard technical based and national perspective.

A final question is given the nature of these options, especially no-regret options, why haven't these been already implemented. Sometimes the no- or low-regret characteristics of these options are associated with non-market sectors or ancillary benefits, thus while they have a positive social present value, they provide lower returns than other options. Furthermore, n many cases, there are high opportunity costs or transaction costs, for example, climate-smart agriculture often involves some loss of land, or up-front labour costs. There can also be underlying barriers, e.g. access to finance, lack of information and awareness, risk aversion to new techniques. These barriers are extremely important. The successful analysis of early low-regret adaptation will need to consider these, otherwise the uptake/implementation of promising options will be low. This necessitates a focus on these issues, alongside technical or economic appraisal.

It is highlighted that the IPCC AR5 confusingly defines 'low-regret policies' as a policy *that would generate net social and/or economic benefits under current climate and a range of future climate change scenarios*, i.e. it is using the former definition of no-regret options. We consider this incorrect and misleading.

Sources: Watkiss et al, 2013; IPCC AR4, 2007; IPCC SREX, 2012; UKCIP, 2006; UKCIP, 2008; HMT, 2009; Wilby and Dessai, 2010; Conway and Schipper, 2011; Ranger and Garbett-Shiels, 2012.

Targeting these existing climate related impacts provides economic benefits today, and also builds resilience to future climate change. As above, this tends to focus on options that have positive social net present values, i.e. which are good to do anyway, but which for various reasons, are not already in place. Typical examples include:

- Sustainable agricultural management (soil and water conservation). In recent years this has been re-labelled as climate smart agriculture, but includes options that have been advanced for many years, such as soil management (e.g. erosion control), conservation agriculture, agroforestry, rain-water harvesting, etc.

- Disaster risk reduction/disaster risk management. There is an obvious overlap between DRM and adaptation, and thus an early focus is preventative action to reduce the impacts of climate-related hazards, i.e. floods, droughts, wind-storms, storm-surge, etc. This includes a focus on DRM options such as early warning systems. However, some of the options that typically fall within DRM may actually be high-regret (e.g. certain types of infrastructure) in the context of a changing climate.

These types of options deliver short-term economic benefits, as they reduce the current impacts and economic costs of climate variability. As these benefits are associated with current activities and arise immediately, they score well in terms of discounted present values. As an example, a recent review (Mechler 2012) reports that the benefits of investing in DRM outweigh the costs of doing so --- on average, by about four times the cost in terms of avoided and reduced losses (with BCs of 5:1 for floods, 4:1 for windstorms). Similar most reviews of climate smart agriculture report high BCrs. However, in many cases these benefits are dependent on the valuation of health or environmental benefits (non-market sectors), and there can sometimes be important opportunity or transaction costs that need to be factored into the analysis.

While the benefits of these options are associated with current activities and arise immediately, many early options will also provide enhanced benefits in the future, under conditions of a changing climate. The analysis of these future benefits is more complex, due to uncertainty, and there is a need to make sure that current actions do not increase vulnerability or risk in the future.

Because of this uncertainty, the most promising low-regret options in this category are often focused on non-technical, ecosystem-based, or community-based activities. This uncertainty also means that structural or engineered adaptation, e.g. major flood protection or water storage projects are not necessarily considered low-regret, at least in all contexts. For these options, which involve longer time-frames, there is a need consider the effects of future climate change, to consider potential changes and avoid mal-adaptation.

In some cases, it is possible to assess some options using conventional appraisal methods, e.g. cost-benefit analysis. However, in many cases these options involve non-market benefits, e.g. the health benefits of DRM, the ancillary environmental benefits of sustainable agriculture. They may therefore require other techniques, e.g. cost-effectiveness analysis or multi-criteria analysis. While, this category of options is considered to be one of the main areas of focus for early adaptation, there is often an overlap with current programmes, e.g. agricultural development or DRR activities. Indeed, in many cases, these options will already be in government or development partner support programmes.

This highlights an extremely important point: an adaptation programme that focuses on the existing adaptation deficit needs to undertake detailed baseline analysis, to assess what options are already included, and where additional options or scale-up of existing options is needed.

Building Capacity

One type of option that is commonly reported as being an early priority and is highlighted in nearly all adaptation plans is capacity building. Capacity building is a broad term (UKCIP, 2008) that involves: gathering and sharing information, i.e. undertaking research, collecting and monitoring data, and raising awareness through education and training initiatives; creating a supportive institutional framework that might involve changing standards, legislation, and best practice guidance, and developing appropriate policies, plans and strategies; and creating supportive social structures, such as changing internal organisational systems, developing personnel, providing the resources to deliver the adaptation actions, and working in partnership. Typical examples include:

- Strengthening of meteorological and climate forecasting/projections.
- Enhanced monitoring (e.g. physical measurements such as hydrological flows, human disease burden, agricultural pests and disease, etc.).
- Vulnerability or risk analysis and mapping.
- Climate information, knowledge and dissemination (including portals) and services.
- Climate research programmes.
- Training.
- Awareness-raising programmes (on risks or adaptation options).
- New (climate) institutional arrangements or institutional strengthening, etc.

Capacity building is an important precursor or complement to successful adaptation, providing the necessary architecture to enable current and future decision making, providing the necessary baseline information to assess current and future benefits, providing critical early actions to allow later options, etc. It is therefore highly relevant as part of a portfolio of measures, providing enhanced information for current (or future) decisions, providing information to raise awareness, strengthening relevant institutions involved in climate change, etc. It therefore has strong overlaps with other areas, either as part of complementary responses (i.e. investing in seasonal forecasting capability to improve early warning systems) or as part of the evidence base for addressing future climate change. Indeed, the literature reports that interventions to address the adaptation deficit (for the more concrete options outline in the sections above) are more effective when implemented in combination with capacity building. As an example, a portfolio of improved seeds, soil and water conservation, better extension services and improved climate information, was found to be most effective in enhancing agricultural production in climate vulnerable areas of Ethiopia (Di Falco and Veronesi 2012). This highlights that successful adaptation will involve a combination of outcome and process based adaptation (technical and socio-institutional interventions).

These capacity building options are generally low cost to implement, although there are sometimes capital costs associated with equipment (e.g. monitoring stations) or training/staff resources. They provide high benefits, which can arise immediately, though these are less direct that the categories above. Their benefits arise from providing the information base and enabling environment to improve the effectiveness and efficiency adaptation options. However, these benefits are often qualitative or non-technical in nature, which makes their analysis more challenging, especially for outcome-based indictors (hence the frequent use of process-based indicators). Some analysis is possible, through the value of information that they provide (see box). When these benefits are included, it is clear that capacity building leads to high benefit:cost ratios: as an example, a review of the cost-benefit studies of enhanced climate services (e.g. seasonal forecasts, information for early warning) have been reviewed and found to produce B:C ratios of at least 4:1 (Watkiss and Hunt, 2014) in terms of current benefits.

While the capacity building benefits in this category are associated with current activities and arise immediately, e.g. from investing in information or capacity today to reduce the adaptation deficit, they also provide benefits for improved future decision on future climate change.

The value of information

In economic terms, investment in capacity building can be justified through the value of information, or through the concept of quasi-option value. Information has a value, as it leads to different actions with learning, and allows higher benefits or lower costs as a result. It is possible to place an economic value on information. To do this, the analysis calculates the value or cost without information, and then compares this to value or cost if learning from this information takes place and action is taken. The difference between these is the economic value of information (VOI) (Teisberg, 2002).

This can be used for assessing the benefits of enhanced information or capacity for decisions or actions today, but it can also be used to improve the decisions for future decisions as well. Indeed, this future concept of VOI has been used in the analysis of alternative climate change mitigation paths, with analysis of the global economic gains from eliminating uncertainty around climate change earlier. In the context of climate change adaptation, better information about future climate change risks is likely to prove beneficial in making decisions on resource allocation for adaptation options. For example, information on changes in temperature and sea-level, or the severity of future droughts, are likely to be important in leveraging resources to manage infrastructure such as sea walls, reservoirs, etc. (Neumann and Price, 2009). This allows more formal economic analysis, as in real options analysis (see later).

2) Building Resilience to the Future

This set of options seeks to build resilience to future climate change. This set of options relates to current (or near-term) decisions that will be exposed to climate change in the future. This differentiates them from actions focused on the current climate (in 1 above) and for future decisions and future climate (in 3 below). In terms of early adaptation, this leads to types of interventions that seek to build resilience at low or zero cost, and information to provide risk reduction.

Building resilience

One of the concepts advanced for early adaptation is building climate resilience, particularly for near-term decisions that have long life-times, i.e. major development policies, land-use change, infrastructure, urban planning, etc. This is sometimes referred to as 'climate proofing', though this term is not recommended (see box for why). The focus is on building resilience against future climate change. While this may sound sensible, the additional marginal costs of building resilience need to be considered against the benefits.

Climate Proofing versus Building/Enhanced Resilience

The term climate-proofing implies actions to protect against all future climate risks, irrespective of costs. This is problematic for two reasons. First, in many cases it is not possible to do this, i.e. to completely climate-proof and there will always be some residual risks. Second, the over-design of infrastructure and programmes to withstand all future risks is an extremely inefficient use of resources, i.e. it will lead to many cases where benefits exceed costs, and climate proofing is not good value (i.e. it is more economically efficient to have some level of residual risks). While it is somewhat more complex, the term building resilience is therefore preferable.

As an example, the economic lifetime of an investment or policy may be relatively short, at least with respect to the major changes from climate change. A major road resurfacing project may only have a 15 year lifetime, which makes it unnecessary to design it for the climate of 2050. Furthermore, even if a major project or investment is exposed to future climate change, these risks (and thus the benefits of resilience) will occur in the future, and need to be discounted when comparing to the additional costs of investment today (see next chapter). In many cases, even if there are benefits in the future, it may not make economic sense to increase up-front capital investment. Finally, due to the uncertainty with future climate change, the benefits of enhanced resilience may only arise under some rather than all futures.

For these reasons, some early resilience building options will represent value-for-money, but many will not. One potential set of low-regret options are in cases where it is possible to introduce *low cost resilience*, is by introducing higher safety margins in long-lived infrastructure at the design stage or during planned replacement cycles, in cases where these have zero or low marginal costs, i.e. low-cost overdesign. This might include, for example, designing storm water drainage capacity to cope with higher future water flows than might arise from future climate change. In general it is more costly to introduce such measures when retrofitting, thus the focus is on new projects or planned replacement cycles, although there can be some exceptions (such as when retrofitting increases efficiency).

This has a strong overlap with the concepts of risk screening and enhanced resilience, i.e. in looking to build resilience in general development programmes and policies (mainstreaming), as well as in the design of specific adaptation options to address future climate change. It also links closely with the information and capacity outlined below and the use of risk information, e.g. in siting of infrastructure to reduce risks.

There are also a number of other potentially low-regret/value-for-money options which seek to introduce alternative concepts to *address future climate uncertainty*. A number of options are highlighted:

One option is to introduce flexibility into the design of infrastructure or policies. As an example, this might involve the use of sea defences that can easily be upgraded in the future with rising sea level (e.g. using soft, ecosystem based options, rather than engineered responses). It can also include flexibility for the future at the design stage, allowing measures or policies to be adjusted later to cope with future climate conditions (e.g. building extra headroom in new developments to allow for further modifications in the future).

Another set of options is to introduce policies/designs that are more reversible, or to reduce life-times (e.g. of infrastructure) so that future replacement cycles can more easily take account of climate change.

Finally, an alternative approach is to design development strategies or options to perform well (though not necessarily optimally) over a wide range of future climate conditions, often termed robustness.

However, there are usually additional costs in building in flexibility or robustness, and the benefits need to be traded off against the benefits these deliver. For these reasons, rather than as a general approach for use in all policies, programmes and plans, these types of low-regret areas of focus will be on:

- Critical infrastructure (e.g. hospitals, water and sanitation plants) or critical nodes (e.g. bridges in the road network), as the loss of these has high direct and indirect costs, and/or involve high costs to replace/repair.
- Long-lived infrastructure that will be expensive to retrofit later. This will potentially include major projects/capital investments such as water storage projects, port facilities, hydro-electric plants, etc. where future climate change may affect not just the assets but future operational performance.
- Irreversible decisions (e.g. land-use change, urban plans).

The justification for early adaptation in all these cases is more complex than for options that address the adaptation deficit, and there is a real trade-off between the level of action and the benefits that are realised.

Enhanced resilience offers potential benefits through the protection of assets or policies to future change - either in terms of the protection of asset/investment in itself to future damage from climate change - or the performance of the policy or asset over its intended lifetime (and thus the delivery of the stream of anticipated benefits). However, as highlighted in the text above, these future (discounted) benefits need to be considered against the additional costs today. For this reason, the focus of early adaptation is likely to be in the cases where low-cost (over-) design is possible, or when investing in critical infrastructure or irreversible decisions.

Robustness, Flexibility and Adaptation Decision Making under Uncertainty

Robustness. Robust options (in the climate change literature) are those which perform well over a wide range of future climate scenarios, rather than performing optimally for one single or central future[11]. While some robust options will meet the definition of low-regrets, not all robust options are no- or low-regret options, and their main advantage is that they provide a better hedge to take account of future uncertainty.

There are new decision support tools which can help to identify robust options, notably robust decision making, a decision support tool that aims to help take robust or resilient decisions today, despite imperfect and uncertain information about the future. This approach is premised on robustness rather than economic optimality, and in that case a robust option may offer better value-for-money than one that is not.

Flexibility. Flexible options are those that allow more effective responses in the future through their flexible design[12]. These allow options to be amended, upgraded or altered through learning. An example would be for upgradeable dykes or barriers that allow increases in future heights (for example, with the use of sand dunes and natural vegetation) rather than a one-off irreversible engineered response.

Associated with this are the concepts of learning, the value of information (see earlier) and option values. It is possible to assess flexibility, learning and future option value in economic terms through the use of real options analysis. ROA is an economic decision support tool that quantifies the investment risk associated with uncertain future outcomes. The approach can be used to consider the value of flexibility, e.g. over the timing of a capital investment, or to adjust the investment as it progresses over time with new information (learning). ROA has been cited as a possible decision tool for adaptation, including in UK's HMT supplementary guidance on adaptation, but in practice it is technically complex and resource intensive to apply.

In the context of flexibility, the primary benefits are linked to the value of information (from learning) and the ability to better resolve future uncertainty. The primary focus is likely to be on large, irreversible up-front capital investments, where there is an opportunity cost of waiting (e.g. where there is a large existing adaptation deficit or a loss of revenue from delaying a project or policy).

Finally, for robustness, the primary benefits are through enhanced performance (and the delivery of more certain benefits) in the context of future climate change uncertainty, i.e. the potential to deliver higher present values across a range of futures, rather than an optimal response to one central future. Again, this will have highest application for major or irreversible decisions with long-life times.

Information and capacity

A closely related option, though separated because of the nature of the benefits, is around *information and capacity* to build resilience or reduce future risks.

This particularly relates to adaptation options that build information that can be used in near-term decisions to take account of future climate change. Examples include:

- Risk/hazard mapping and the use of this information in siting infrastructure or land-use planning to reduce exposure to the future risks of climate change. This might use information (risk maps)

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[11] Note that this notion of climate robustness differs slightly from that used in statistical analysis, where robust statistics are statistics that perform well for data drawn from a wide range of probability distributions. Perhaps the best-known example of this concept is that of the median which is a robust measure of the central tendency, (average), given alternative distributions. This contrasts with the mean that is a poor measure of central tendency, given its susceptibility to influence from e.g. outliers in a distribution.

[12] The definition of flexibility used in the climate literature differs to its usual use in economics where the flexibility of markets – and specifically the ability for prices and quantities to adjust between equilibria – is important.

to inform set-back zones in low lying coastal areas at risk of future sea-level rise (climate risk screening).

It might also include the use of similar information to raise awareness for individuals to change decisions, or to change regulations or standards to reflect future impacts.

Note that this also needs to include the investment in capacity and communication/ dissemination of this information, to ensure it reaches those end-users who can derive benefits from it.

The main benefits of investing in information and capacity to improve near-term decisions to address future climate change are through the value of information (see earlier). As an example, risk mapping has the potential to provide information to reduce future property damage (e.g. from flooding associated with climate change). It also helps people to make decisions on where to live and what prevention measures to take (World Bank, 2010).

Investing in information and supporting capacity has potentially high benefit:cost ratios, and as it generally involves low costs, it is a low-regret option.

However, while the generation of information (e.g. risk maps) are low cost, the implementation of these in decisions such as land-use policy has a more complex balance of costs and benefits.

For example, the use of this information in land-use planning produces benefits of considerable value, but the cost of producing these benefits is high also. As an example, set-back zones or land-use constraints are likely to lead to high opportunity costs, e.g. from the foregone opportunity of the use of the land. This may be a particular issue if large areas are included or high protection levels are put in place (against risks that may or may not occur). Similarly, options that seek to increase standards (e.g. building codes) will involve increase costs (generally speaking) and there is therefore the issue of discounted and uncertain future benefits, and the level of protection (or over-protection) included. For this reason, while producing this information is a low-regret option, the subsequent use of it will require a much more considered analysis.

3) Early Action for Addressing Future Challenges

This final category of adaptation sits within the final part of the iterative framework, in relation to the long-term risks of climate change. These have to address the high uncertainty involved.

Iterative Adaptation Pathways

This category of action focuses on longer-term challenges, i.e. on future decisions to address future climate change. While these major events happen in the future, postponing adaptation may not be sensible if future impacts are potentially large or even catastrophic, irreversible, or if adaptation responses have a long lead-time.

The focus is not on identifying large-scale interventions today, but instead on early low-regret options that are a priority for early adaptation, i.e. to start preparing for these future challenges. These involve iterative plans to take account of uncertainty, with early monitoring and pilots, to ensure future options are kept open and lock-in is avoided. These approaches are often known as adaptive management**,** though the term adaptation pathways is also becoming widely used (Downing, 2012). The approach was recently recommended in the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC, 2012) and the IPCC 5th Assessment Report, which used the term iterative climate risk management.

Adaptive management is an established approach that uses a monitoring, research, evaluation and learning process to improve future (management) strategies. In the adaptation context, the approach identifies possible future risk or impact thresholds associated with major future climate change. It then assesses options (or portfolios of options) that can respond. This may start with early measures (e.g. to address current climate variability) and then progress to more major (and expensive) interventions. Importantly indicators are identified to allow the monitoring of risks over time, and provide the cycle of evaluation and learning to update plans in the future. The focus is on the management of uncertainty over time, allowing adaptation to develop within a process of learning and iteration. The results of these iterative assessments are often presented as pathways or route maps. While most applications have been at the project level, notably for sea level rise (e.g. Thames Estuary 2100 project, EA, 2009), there are now examples emerging of more strategic or even national level plans (see the box below for an example from Ethiopia). More detailed are provided in the later section on decision making under uncertainty.

The advantage of this approach is that rather than taking an irreversible decision now about the 'best' adaptation option – and investing in an option which may or may not be needed depending on the level of climate change that arises - it encourages decision makers to adjust plans over time as the evidence emerges (Reeder and Ranger, 2011), such that that options can be brought forward– or delayed to a later time period – depending on how climate change actually evolves.

As these iterative adaptation pathways tend to be aligned to specific sectors or risks, there is a large variation in the possible options. However, typical examples of low-regret/early value for money action in these pathways include the development of the iterative risk plans, to identify major risks and develop response plans and early actions. They also include the associated enhanced monitoring, climate information and early research. These are linked to the iterative plans, and are designed to provide information or to pilot promising options. For example, they might be associated with tide gauge or sea surface temperature monitoring, to start tracking coastal changes, or they might be focused on pest and disease surveillance or forest health to look at early signs of a changing climate.

It is highlighted that the early actions in this category are unlikely to be large-scale investment (though these may come later) and low-regret options will be focused on information and some early actions to target the current adaptation deficit. They are therefore low cost. The benefits of these plans are mostly focused on the future, and they do not generally generate immediate outcome-based benefits. Their main benefit is the value of information produced (see earlier box), noting there are formal economic techniques that can help identify and value this information. These early steps can also be seen from a risk or insurance based perspective.

Transformation

The final category is transformation or transformative adaptation. This term is not well defined in practical terms, but relates to long-term major, irreversible or systemic risks (structural/societal/economic), which are beyond the limits of conventional adaptation. These may require major long-term economic or societal transformation (e.g. major population shifts, major livelihood shifts).

Transformative adaptation is unlikely to be an early low-regret priority today. However, there may be an early low-regret option to start developing the transformative vision - and identifying potential incremental steps towards this - when there are possible limits to adaptation in the long-term.

To illustrate, short-term adaptation may sustain current livelihoods or patterns of development in locations that will be unsustainable in the long-term e.g. due to the exceedance of major bio-physical, societal or economic thresholds. In such a case, the early option will be to identify these risks, along with a long-term vision of what transformational change might look like. It will also identify any short-term actions that prevent future lock-in, and identify the intermediate (incremental) steps towards the long-term vision, taking account of uncertainty.

Methods for Decision Making Under Uncertainty and Application to Adaptation

Cost-benefit analysis

Social cost-benefit analysis (CBA) is frequently used in Government economic appraisal (e.g. HMT, 2007). It aims to value all relevant costs and benefits of a proposed project/programme to society, allowing comparison of costs and benefits in a common metric – money. It therefore takes a social welfare maximisation perspective. CBA compares options using net present values (NPV), calculated as total discounted benefits minus total discounted costs, or benefit:cost ratios. As it identifies whether benefits exceed the costs, it can justify intervention, and allows resources to be allocated efficiently against other priorities, facilitating NPV ranking of options. In addition to a deterministic analysis, CBA may use expected values, (the weighted average of all possible values of a variable, where the weights are the probabilities, HMT, 2007), and expected utility – if the risk preferences of those affected are known - or a measure of uncertainty preference, where these are known and the probabilities of outcomes are unknown. However, in reality such preferences are often not understood and excluded/imposed by the analyst/decision-maker (Pearce and Nash, 1981).

Application to Adaptation

CBA is widely used and has many advantages, though its obvious limitation is it requires all elements to be expressed in monetary terms: in practice it is difficult to value all costs and benefits, particularly in non-market sectors. This present a challenge for adaptation, as capacity building and non-technical options are difficult to quantify and value, and thus may be given lower priority or omitted.

In the application of CBA to climate adaptation, benefits are defined as the avoided damage costs of climate change. If benefits outweigh the costs of a given adaptation measure, there are net benefits and the adaptation measure is economically efficient, meeting the principal criterion of CBA (noting the trade-off with residual risks as well). CBA has been used in a number of more conventional adaptation assessments (e.g. Nkomo and Gomez, 2006, ;ECA, 2009: World Bank, 2010). These primarily use scenario-based impact assessment to appraise with a predict-then-optimise framework, estimating baseline damage costs then applying CBA to appraise responses under alternative climatic and socio-economic futures. However, the consideration of uncertainty has largely been ignored, and the extent of analysis is to test multiple scenarios/models one at a time.

It is relatively easy to incorporate risk within CBA using expected values. However, this can provide misleading results when probabilities are not known. For example, for a set of climate outcomes that unknown with respect to the sign of change (e.g. whether increases or decreases in rainfall will occur), the optimal CBA response to the mean of the multiple simulations is likely to orientate the response towards minor deviations from the current. This has the potential for a resource allocation that is insufficient to cope with more extreme outcomes.

Cost-effectiveness analysis

Cost-effectiveness analysis is used to compare the costs of alternative ways of producing the same or similar outputs. As such, it is a relative measure, providing comparative information between choices. CEA has been widely used for environmental policy, because it avoids the need to provide monetary valuation of benefits, e.g. in flood protection alternative ways of achieving defined levels of acceptable risk can be compared. At the project level, CEA can be used to provide a ranking of alternative options using cost per unit benefit (i.e. cost-effectiveness). At the programme or policy level, it can assess the least cost solution to achieve pre-defined targets or objectives - or identify the largest benefits possible with available resources. In both cases, marginal abatement cost (MAC) curves allow identification of the most cost-effective options and the least-cost cumulative effectiveness.

The key strength of CEA is its applicability where monetary valuation is difficult or contentious. It has become the main appraisal method for greenhouse gas mitigation, using MAC curves. Most applications present individual curves, thus omit risk or uncertainty, though sensitivity analysis is possible (e.g. providing curves for alternative energy prices or discount rates: CCC, 2008). While it is possible to use stochastic approaches in CEA to assess changes in ranking and target levels, this is rarely undertaken. In principle, preferences relating to risk or uncertainty can also be incorporated into CEA, though this is exceptional in practice.

Application to Adaptation

To date the number of adaptation CEA studies is relatively small. Boyd et al. (2006) assessed future climate change impacts on household water deficits across a range of climate scenarios in South-East England and considered the cost-effectiveness of demand and supply options for managing public water supply. MAC curves were constructed to assess how to eliminate the household water deficits at minimum cost. Such studies highlight that applying CEA to adaptation involves major differences to the mitigation context. Mitigation options are compared directly across sectors with a single globally comparable common metric ($/t$CO_2$). In contrast, adaptation is a response to specific local, regional or national level impacts across a variety of metrics, e.g. adaptation to sea level rise (SLR) involves protecting people, reducing erosion, conserving ecosystems, and a single metric may omit categories and may not identify the most holistic option. Adaptation benefits are also location and technology specific, and time-dependent, thus unit effectiveness changes over time. CEA also tends to focus on technical options, because these can be easily quantified, omitting (or giving lower priority to) capacity building and non-technical options. It also considers options discretely, in a linear and sequential order, which is at odds with the adaptation literature on portfolios and inter-dependencies in managing uncertainty (IPCC, 2012).

Multi-Criteria Analysis (MCA)

Multi-Criteria Analysis (MCA) is a decision support tool that allows consideration of quantitative and qualitative data together in ranking alternative options. The approach provides a systematic method for assessing and scoring options against a range of decision criteria, some of which are expressed in physical or monetary units, and some which are qualitative. The various criteria can then be weighted to provide an overall ranking of options. MCA has been widely applied in the environmental domain. It has also been used as a complementary tool to support cost-benefit analysis in appraisal, to consider the performance of options against criteria that may be difficult to value or involve qualitative aspects.

Application to Adaptation

MCA does have considerable potential for adaptation. Criteria can be included to consider uncertainty or various complex elements of good adaptation, and the approach brings the flexibility to work with qualitative information, which is particularly useful given there are often data gaps. As an example, previous adaptation MCAs have considered criteria of robustness, low/no regret characteristics or flexibility, as well as co-benefits and synergies with mitigation (van Ierland et al, 2007). However, the analysis can be somewhat subjective in nature, especially in relation to uncertainty, as it tends to work with individual scenarios, against which options are assessed. This makes it more difficult to incorporate the trade-offs over time and to fully incorporate climate change uncertainty (i.e. how benefits of different adaptation options vary).

Real options analysis

The concept of real options analysis derives from methods developed in the financial markets. A financial option gives the investor the right, but not the obligation, to acquire a financial asset in the future, allowing them to see how market conditions play out before deciding whether to exercise the option. This transfers risk from the buyer to the seller, making the option a valuable commodity. Options analysis quantifies this value, based on how much the risk transfer is worth (Merton, 1973).

The same insights are useful for investment in physical assets (hence 'real' options), in cases where there is risk/uncertainty attached to future values (McDonald and Siegel, 1986). Real options analysis (ROA) quantifies the investment risk with uncertain future outcomes. It is particularly useful when considering the value of flexibility with respect to the timing of capital investment, or adjustment of the size and nature of investment over a number of stages in response to unfolding events. In the adaptation context, this allows for the analysis of flexibility, learning and future information, particularly relevant for uncertainty.

ROA typically gives two types of result that set it apart from conventional economic analysis. The first applies to projects that are cost-efficient under a deterministic analysis: ROA may show that it makes more sense to wait for the outcome of new information, rather than investing immediately, if the benefits of the new information outweigh the costs – i.e. deferred benefits – of delaying implementation. The value of waiting will then be higher if the degree of uncertainty regarding the return of the project is greater; and the duration of the period of waiting before information is gained is shorter. The value of waiting needs to be balanced against the cost of waiting, because while waiting, the project will not be delivering benefits (Dixit and Pindyck, 1994). The second applies to projects which fail a conventional CBA under deterministic analysis, but under conditions of uncertainty it may make financial sense to start the initial stages. This arises because ROA helps understand how project value evolves during development: there will often be flexibility to adjust the project as it proceeds and it can expand, contract or stop. ROA can incorporate this value of flexibility (which is omitted in standard economic analysis). As with CBA, effective treatment of risk preferences depends on the ability of the analyst to describe these accurately.

The approach has been used for low-carbon energy investments, see Martínez Ceseña et al. (2013) for a review, including carbon capture and storage (Eckhause and Herold, 2013), nuclear (Zhu, 2012). The approach has also been used for climate policy analysis: Fuss et al. (2009) and Reuter et al. (2012) analyse climate policy uncertainty and market risk for energy investment decisions, identifying opportunities for improving mitigation policy to reduce policy risk. Anda et al. (2009) considers climate policy under uncertain impacts including 'fat tail' probability distributions, using ROA to formulate rules for selecting emission targets and the value of future flexibility from interim climate policy and new knowledge. Such studies show ROA can be useful under three conditions: first, the investment decision is irreversible; second, the decision-maker has some flexibility when to carry out the investment (single step, or in stages); third, the decision-maker faces uncertain conditions and by waiting they gain new information regarding the success of the investment.

Application to adaptation

ROA has been advanced as a decision support tool for adaptation (HMT 2009), as it aligns closely with the concepts of iterative decision making. ROA can be carried out in a variety of ways but the most relevant to adaptation is dynamic programming, an extension of decision-tree analysis. This defines possible outcomes, and assigns probabilities, defining the resolution of uncertainty at each branching point. ROA calculates option values based on the expected value over all branches, contingent on making the optimal choice at each decision-point. The optimal decision is evaluated based on all the possible outcomes downstream of that decision in the tree. This ROA value can be compared to a normal (probability-weighted average) calculation.

A key strength for adaptation is the economic analysis of investing now versus waiting, and the value of flexibility, i.e. identifying whether the marginal cost (lower initial benefits) of added flexibility is offset by the option value for future learning. ROA can also support initial enabling steps to help secure projects for future development. ROA investment rules favour adaptation projects that have substantial near-term benefits, relatively small variance in outcome scenarios, and/or the need to wait for long periods of time before new information arises that affects the investment decision. This will be the case when there is an existing adaptation deficit that the investment can reduce, such as current flood risk, and/or if there is a long period between the decision to proceed and the scheme being built e.g. from planning processes. The approach is most relevant to large, capital intensive investments such as flood protection or water storage. Capacity building, no-regret or soft options are only likely to be evaluated to the extent they are initial steps in keeping open possible future investment options.

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There are applications of ROA to adaptation. HMT (2009) provides supplementary economic appraisal guidance with a hypothetical ROA for future uncertain sea level rise, comparing a fixed-height sea wall against one that is upgradable, highlighting that ROA selects the latter. However, the use of ROA with climate projections and real project data involves a step change in complexity. Most applications have focused on sea-level rise, which lends itself to ROA due to the high capital investments and the nature of single, directionally bounded, gradual change. Linquiti and Vonortas (2012) report that framing investments in coastal protection as real options leads to better use of resources in Dhaka and Dar-es-Salaam. Kontogianni et al (2013) use ROA to assess the value of maintaining flexibility (e.g. scaling up or down, deferral, acceleration or abandonment) to engineered structures in Greece. Scandizzo (2011) applies to assess the value of hard infrastructure, restoration of mangroves and coastal zone management options in Mexico, concluding ROA highlights the value of gradual and modular options. Applications to other areas are rarer and often involve more complexity. Jeuland and Whittington (2013) applied ROA to water investment planning on the Blue Nile to identify flexibility in design and operating decisions for a series of large dams. Their results do not identify a single 'best' investment plan, but highlight configurations robust to poor outcomes but flexible enough to capture upside benefits of favourable future climates. Other examples include applications to agricultural irrigation in Mexico (World Bank, 2009) and Gersonius et al (2013) on urban drainage infrastructure in West Garforth, England.

Important lessons emerge from these applications. First, the technique can be conceptually consistent with iterative adaptation, but data constraints may be a barrier to use, especially since key inputs are probabilistic climate information and quantitative impact data, noting the scope for the incorporation of risk preferences also remains limited. Furthermore, adaptation ROA needs to identify decision points in complex evolving climate pathways. Finally, the complexity of the approach is likely to require expert application which will constrain widespread up-take.

Robust decision making

Robust Decision Making (RDM) is a decision-support method premised on robustness rather than economic optimality. RDM involves testing strategies across a large number of plausible futures. It is often described as decision making under *deep uncertainty*, i.e. where little or no probabilistic information is available. In so doing, it helps to identify robust options or strategies, i.e. which perform well over a wide range of scenario futures. A key aim is therefore to help take robust decisions today, despite imperfect and uncertain information about the future.

The conceptual framework for RDM and applications of the approach are long-established (Matalas and Fiering, 1977) but the advent of computing power has allowed major advances. The formal application has a series of steps (Lempert et al, 2000: Groves and Lempert, 2007) beginning by structuring the problem, proposing alternative strategies and identifying performance measures. Levels of uncertainty characterizing these strategies and performance measures are determined by assigning uncertainty parameters (i.e. a range of potential values) to key variables. Depending on the application, these can be derived using modelling techniques and/or stakeholder consultation. For example, the potential range of per capita water demand for California in 2050 expresses uncertainty relating to a key variable in water resource planning (Lempert and Groves, 2010). Each strategy is then assessed over a wide range of future scenarios. Qualitative and quantitative information is incorporated in a computer modelling interface that adopts data sampling algorithms to analyse strategies over large ensembles (thousands or millions of runs) reflecting different plausible future conditions. Strategies are then "stress tested" to identify potential vulnerabilities or weaknesses. The combinations of parameters for which uncertainty is most important can be statistically derived and a summary of key trade-offs across the most robust strategies can be constructed. At this point there is a role for preferences relating to uncertainties and their associated outcomes to be incorporated in the analysis, since these inform the choice of trade-offs to be given most weight, as well as the weights to inform the trade-offs themselves.

Application to Adaptation

RDM has attributes that align with adaptive management and the technique has been applied to adaptation. Lempert and Groves (2010) applied the method to the Urban Water Management Plan in California, evaluating a range of climate and socio-economic scenarios. Principal performance measures and uncertainties were identified, and alternative management strategies were assessed within a water planning model. Adaptive strategies were assessed against six criteria through a succession of iterative 5-year signposts, with performance measured using projected present value (PV) costs against PV shortage costs. The analysis identified eight response strategies, four static and four adaptive, finding the latter led to fewer vulnerable states. Dessai and Hulme (2007) present an example focused on climate robustness for an English water resource zone, and the implications of climate change on water supply options. Their findings indicated the existing water plan was robust across the scenarios evaluated, primarily because it had already mainstreamed climate change by using an extreme dry scenario. More recent applications include application to water management in the Colorado river (Groves et al, 2013), flood risk management in Ho Chi Minh City in Vietnam (Lempert et al, 2013) and planning coastal resilience for Louisiana (Groves and Sharon, 2013), flood management in the UK (Frontier, 2013) and dams (Nassopoulos et al, 2012).

These applications suggest that when future uncertainties are poorly characterised or probabilistic information is limited/unavailable, RDM is a useful tool and force the decision-maker to make explicit his/her preferences for the importance of relative uncertainties in the model inputs. However, the lack of quantitative probabilities can make it more subjective, influenced by stakeholders' perceptions. The formal application also has a high demand for quantitative information, computing power, and expert resources.

Portfolio theory

Portfolio Analysis (PA) originated in the financial markets as a way of utilising portfolios of assets to maximise the return on investments, subject to a given level of risk. The principle is that spreading investments over a range of asset types spreads risks at the same time. Since individual assets are likely to have different and unpredictable rates of return over time, an investor may be better advised to maximise the expected rate of return and minimise the variance and co-variance of their asset portfolio as a whole, rather than managing assets individually (Markowitz, 1952). As long as the co-variance of assets is low then the overall portfolio risk is minimised, for a given rate of overall return. Aggregate returns are therefore likely to be higher when low returns on an individual stock are at least partly offset by higher returns from other stocks during the same period.

PA helps in the design of such portfolios. It highlights the trade-off between the returns on an investment and the riskiness. It measures risk by estimating the variance (standard deviation) of the portfolio return, thus a portfolio with a relatively high (low) variance is judged to have a higher (lower) risk. The information on returns and risks is used to identify a portfolio that most closely matches preferences. The method starts by defining options, and constructing feasible portfolios. Investment returns (benefits) are then defined and measured. This can include physical or economic metrics, e.g. quantity of water conserved or NPV. The risk is then characterised in terms of the variance or standard deviation around the mean, using probabilities of alternative outcomes to estimate the Expected NPV (ENPV) (the sum of products of outcomes and their associated probabilities). The variance of the NPV expresses the risk that the actual return will differ from expected return. Following this step, the risk-return data for each portfolio is estimated by multiplying the ENPV of each asset in the portfolio by the proportion of each asset. This allows identification of efficient portfolios, i.e. with highest expected return for a given risk or – equivalently - lowest degree of risk for a given mean rate of return (Aerts et al. 2008). The results are plotted in terms of expected return and variance that identifies an efficiency frontier. Portfolios below the efficiency frontier (low returns for high risk) are omitted. Finally, the decision-maker then chooses a portfolio from the efficiency frontier that best represents their risk-return preferences, noting risk-averse and risk-neutral risk decision-maker would choose different portfolios.

Application to Adaptation

The principles of diversification and use of portfolios have high relevance for adaptation. PA allows analysis of these in economic terms. It helps in selecting a set of options that, together, are effective over the range of possible projected future climates, rather than a single option best suited to one possible future.

However, to date there are few applications to the adaptation context. Crowe and Parker (2008) is perhaps the best-known, providing an empirical analysis of selecting genetic material to be used for the restoration/regeneration of a forest under uncertain climate change in Canada. The study combines RCM data with a climate impact model to estimate how different seed sources perform at specific sites under alternative climate futures. It finds that current locations of seed populations are poor predictors of optimal future locations, confirming the need for a broad portfolio of seed sources to maintain the genetic range. Hunt (2009) applied PA to local flood management in the UK. Three alternative adaptation measures were considered for the portfolio: hard defences; flood warning systems; and property-level resilience. The portfolio returns were measured by NPV and a clear, positive, relationship was found between return and variance, highlighting a trade-off between higher NPV of hard defences and higher uncertainty of return, with a number of portfolios found to be sub-optimal.

These case studies demonstrate that for PA to be useful, sufficient data is needed including the average effectiveness (or expected return), the variance, and the co-variance of return for each option over the range of climate scenarios. A minimum level of effectiveness also needs to be defined. PA also requires probabilistic climate information to be imposed, or an accepted assumption, such as the equal weighting of alternative scenarios. The main strength of the approach is that it provides a structured way of accounting for uncertainty using combinations (portfolios) of options, which individual adaptation options do not allow. It can measure "returns" using various metrics, including physical effectiveness or economic efficiency. The use of the efficiency frontier is an effective way of presenting trade-offs. The disadvantages include that it is resource intensive, requires a high degree of expert knowledge, and relies on the availability of quantitative data.

Iterative risk management

Iterative risk management (IRM) – also known as adaptive management - is an established approach that uses a monitoring, research, evaluation and learning process (cycle) to improve future management strategies. Its application to adaptation has long been recognised, most recently as 'adaptation pathways' (Downing, 2012) or route maps (Haasnoot et al, 2013).

While the concepts are established, the inclusion of economic appraisal within IRM is less common, and so less methodologically developed. The overall method includes the following steps (Reeder and Ranger, 2011). First, an understanding of the current climate variability and any existing adaptation deficit are made, followed by the identification of major future risks from climate change. Future risk scenarios are then constructed and the analysis investigates and identifies vulnerability/impact thresholds that could trigger risks when coping capacity is exceeded, as well as effective indicators. The importance of alternative thresholds may in turn be determined by the risk/uncertainty preferences of the decision maker(s). The analysis then moves to adaptation, identifying possible adaptation options or portfolios that could be implemented in response to different threshold levels, and develops pathways of options. Finally, the analysis considers options against economic and other criteria and recommends a feasible, preferred route or pathway, as well as key monitoring variables. A key element of the approach is the link to on-going monitoring and a cycle of review, which allows learning and revision of the strategy over time.

Application to Adaptation

IRM has been widely recommended for long-term adaptation (Haasnoot et al, 2013) including major change, such as extreme sea level rise. One of the most frequently cited adaptation applications is the Thames Estuary 2100 project (EA, 2011). This developed a tidal flood risk management plan for London, developing a short-, medium- and long-term programme to address sea level rise, leaving major irreversible decisions as far as possible into the future to make best use of available information. Four future SLR scenarios were considered, including an extreme scenario (>2m by 2100). A series of defence options were appraised using CBA, complemented by Multi-Criteria Analysis to capture indirect/ancillary impacts. The plan recommended maintenance of existing flood defence system initially, followed by a programme of renewal and improvement, with a decision on the 'end-of-century' option by 2050 (including a new downstream Thames Barrier), noting this decision will depend on conditions at that time. The project included a monitoring and evaluation strategy, with established decision points. If monitoring reveals SLR is happening more quickly (or slowly), options can be brought forward (or put back). Similar pathway approaches have also been developed in the Netherlands (see Haasnoot et al. this issue). IRM concepts are also starting to be applied at national level (e.g. Watkiss et al, 2013).

The use of such iterative planning aims to build adaptive capacity, implement early low and no-regret options, and identify areas of long-term concern that warrant early action to ensure flexibility is incorporated, risks of lock-in are minimized and future options are kept open. The key advantage is that rather than taking an irreversible decision now– which may or may not be needed - decisions are adjusted over time with evidence (Reeder and Ranger, 2011). This helps ensure that appropriate decisions are taken at the right time, ideally with reference to the risk preferences for the given context. The economic appraisal step within IRM is flexible. It can use qualitative tools (e.g. MCA) or economic tools (CBA) within a framework of uncertainty. The disadvantages of the approach are in the identification of risk thresholds. As a result, the principle application to date has been for (directionally bounded, gradual) SLR. Other studies show the challenges in applying to other sectors (Watkiss et al, 2013) such as agriculture, due to the combination of several climatic parameters, multiple impact risks (with different thresholds), and complex socio-economic and institutional baselines. These problems are compounded with scale and geographical aggregation. Application can also be challenging due to the dependencies between options within a pathway, and the need to balance technological options with strategic and non-structural options for implementation.

Other approaches

While the decision support tools listed above – both conventional and for considering uncertainty – are the main ones reported in the literature, a number of other methods have been proposed (Boyd and Hunt, 2006). The simplest approach, which is included as standard in most economic appraisal guidance for cost-benefit analysis (e.g. HMT, 2007: 2011) is for sensitivity analysis, which focuses on assumptions that have a potentially significant effect on the study's results. It is also possible to use switching values, which examine whether a low or high value of a particular attribute/impact/benefit would alter the project appraisal and the attractiveness of the project. These also include extended conventional expected net present value (ENPV) analysis (where probabilities are known) to consider risk preferences, for example using the expected utility criterion. It is also possible to use expected value-risk analysis (or risk-benefit plotting), which involves comparing the ENPV and 'riskiness' of each option under consideration (where one indicator of 'riskiness' is standard deviation), to investigate the ranking of different levels of ENPV and 'riskiness'. It is also possible to use 'non-probabilistic' criteria, which involve the application of predefined rules to outcome arrays. The maximin criterion, for example, requires the decision-maker to identify the 'lowest' NPV that could result from each adaptation option, and then to select the largest of these 'lowest' outcomes, i.e. maximise the minimum NPV. This focuses on the worst possible outcome associated with each option and is thus risk-averse. Alternatives include other criteria, such as the minimax (regret) criterion, which is a more cautious approach in which the decision-maker should minimise the maximum regret, and the maximax criterion, which is a more optimistic decision-support criterion in which the decision-maker should opt for the option with the highest possible outcome. While these are potentially of relevance, other than sensitivity analysis, the review has found no policy relevant applications of these additional techniques.

European Policy Review

The Commission began developing a specific EU adaptation policy response in 2005, with the founding of a dedicated working group of the ECCP II, leading to a Green Paper (CEC, 2007). This was followed by a White Paper (CEC, 2009).

In 2013, the EU published an EU Strategy on adaptation to climate change (EC, 2013a) with a supporting impact assessment (EC, 2013b, c, d):

•16/04/2013 - COM (2013) 216 - An EU Strategy on adaptation to climate change

•16/04/2013 - SWD (2013) 131 - Summary of the Impact Assessment

•16/04/2013 - SWD (2013) 132 - Impact Assessment Part 1

•16/04/2013 - SWD (2013) 132 - Impact Assessment Part 2

There were a large number of annexes:

•30/07/2013 - SWD (2013) 299 - Principles and recommendations for integrating climate change adaptation considerations under the 2014-2020 European Maritime and Fisheries Fund operational programmes .

•18/06/2013 - Council conclusions on the EU Adaptation Strategy.

•16/04/2013 - COM (2013) 213 - Green paper on the insurance of natural and man-made disasters.

•16/04/2013 - SWD (2013) 133 - Climate change adaptation, coastal and marine issues.

•16/04/2013 - SWD (2013) 136 - Adaptation to climate change impacts on human, animal and plant health.

•16/04/2013 - SWD (2013) 137 - Adapting infrastructure to climate change.

•16/04/2013 - SWD (2013) 138 - Climate change, environmental degradation and migration.

•16/04/2013 - SWD (2013) 135 - Technical guidance on integrating climate change adaptation in programmes and investments of Cohesion Policy.

•16/04/2013 - SWD (2013) 139 - Principles and recommendations for integrating climate change adaptation considerations under the 2014-2020 rural development programmes.

•16/04/2013 - SWD (2013) 134 - Guidelines on developing adaptation.

There were also a number of other related documents:

•16/04/2013 - Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient.

•IP/13/329 - Strengthening Europe's preparedness against natural and man-made disasters.

EU 2013 Adaptation Strategy

Building on the White Paper, and Member State initiatives, the EU launched the 2013 Adaptation Strategy, highlighting the need to deepen experience and to have a systematic exchange of best practice on how to adapt to climate change. This covered the whole of the EU while respecting principles of subsidiarity and proportionality and the rights enshrined by the Charter of Fundamental Rights of the European Union.

The overall aim of the EU Adaptation Strategy is to *contribute to a more climate-resilient Europe. This means enhancing the preparedness and capacity to respond to the impacts of climate change at local, regional, national and EU levels, developing a coherent approach and improving coordination*.

It also set out relevant issues in relation to:

- **Uncertainty**. *Uncertainty regarding the trajectory of greenhouse-gas emissions, future impacts of climate change and related adaptation needs remains a challenge for policy making in this area. Yet, uncertainty cannot be seen as a reason for inaction. It notably calls for a strong emphasis on incorporating win-win, low-cost and no-regret adaptation options. These include sustainable water management and early warning systems. Ecosystem-based approaches are usually cost-effective under different scenarios. They are easily accessible and provide multiple benefits, such as reduced flood risk, less soil erosion, improved water and air quality and reduced heat-island effect*.
- **DRM linkages**. *Adaptation action is closely related and should be implemented in synergy and full coordination with the disaster risk management policies that the EU and the Member States are developing*.
- **Growth, jobs and competiveness**. Adapta*tion action will bring new market opportunities and jobs, in such sectors as agricultural technologies, ecosystem management, construction, water management and insurance. European companies, including SMEs, can be early first movers in developing climate-resilient products and services and grasp business opportunities worldwide. In line with the Europe 2020 Strategy, the Adaptation Strategy will help the EU move towards a low-carbon and climate-resilient economy, and will promote sustainable growth, stimulate climate-resilient investment and create new jobs*.

The Strategy identifies three themes,:

- Promoting action by Member States
- Better informed decision-making
- Climate-proofing EU action: promoting adaptation in key vulnerable sectors

and identified eight actions:

- Encourage all Member States to adopt comprehensive adaptation strategies;
- Provide LIFE funding to support capacity building and step up adaptation action (2013-2020);
- Introduce adaptation in the Covenant of Mayors framework (2013/2014);
- Bridge the knowledge gap;
- Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe;
- Facilitate the climate-proofing of the Common Agricultural Policy (CAP), the Cohesion Policy and the Common Fisheries Policy (CFP);
- Ensuring more resilient infrastructure;
- Promote insurance and other financial products for resilient investment and business decisions.

Promoting action by Member States

While recognising the recommended instrument at global level, under the UN Framework Convention on Climate Change, is national adaptation strategies, the Strategy sets out the importance to ensure joint approaches and full coherence between national adaptation strategies and national risk management plans. It also supports the exchange of good practice between Member States, regions, cities and other stakeholders. It aims also to build on the urban adaptation strategies, following the model of the Covenant of Mayors, an initiative of more than 4000 local authorities voluntarily committed to improving the quality of urban life by pursuing EU climate and energy objectives. Three actions are identified.

Action 1: Encourage all Member States to adopt comprehensive adaptation strategies

The Commission is providing guidelines for formulating adaptation strategies. They are designed to help EU countries to develop, implement and review their adaptation policies. They cover aspects which are missing from existing adaptation strategies, such as cross-border issues, and the need to ensure coherence with national disaster risk management plans. By 2014 the Commission will develop an adaptation preparedness scoreboard, identifying key indicators for measuring Member States' level of readiness. In 2017, basing itself on the reports it receives as set out in the Monitoring Mechanism Regulation and on the adaptation preparedness scoreboard, the Commission will assess whether action being taken in the Member States is sufficient. If it deems progress to be insufficient, by reference to the coverage and quality of the national strategies, the Commission will consider without delay proposing a legally binding instrument.

Action 2: Provide LIFE funding to support capacity building and step up adaptation action (2013-2020).

The Commission will promote adaptation particularly in the following vulnerable areas:

- cross-border management of floods, fostering collaborative agreements based on the EU Floods Directive;
- trans-boundary coastal management, with emphasis on densely populated deltas and coastal cities;
- mainstreaming adaptation into urban land use planning, building layouts and natural resources management;
- mountain and island areas, with emphasis on sustainable and resilient agricultural, forestry and tourism sectors;
- sustainable management of water; combating desertification and forest fires in drought-prone areas.

The Commission will support the establishment of vulnerability assessments and adaptation strategies, including those with a cross-border nature. The Commission will promote awareness-raising on adaptation, including indicators, risk communication and management.

Action 3: Introduce adaptation in the Covenant of Mayors framework (2013/2014).

The Commission, on the basis of the model of the Covenant of Mayors initiative, will support adaptation in cities, notably by launching a voluntary commitment to adopt local adaptation strategies and awareness-raising activities.

Better informed decision-making

The Strategy highlights that substantial knowledge gaps need to be filled and that a solid knowledge base is also essential to drive innovation forward and support the market deployment of innovative climate adaptation technologies. Two actions are identified, one of which links to Horizon 2020. It is highlighted one of the key gaps is **information on damage and adaptation costs and benefits**, and ECONADAPT will provide valuable information towards this. The linkage to the further development of the **Climate-ADAPT** platform is also highly relevant, and ECONADAPT will ensure strong linkages with the EEA towards this.

Action 4: Bridge the knowledge gap.

The key knowledge gaps are:

- information on damage and adaptation costs and benefits;
- regional and local-level analyses and risk assessments;
- frameworks, models and tools to support decision-making and to assess how effective the various adaptation measures are;
- means of monitoring and evaluating past adaptation efforts.

As part of the implementation of the Strategy, the Commission will further work with Member States and stakeholders in refining these knowledge gaps and identifying the relevant tools and methodologies to address them. The findings will be fed into the programming of Horizon 2020 (2014-2020) and will address the need for better interfaces between science, policy making and business. They will also be used to improve the information available on Climate-ADAPT.

The Commission will promote EU-wide vulnerability assessments, taking into account, inter alia, the cross-sectoral EU overview of natural and man-made risks that it will produce in 2013. It will notably support the Joint Research Centre in its work on estimating the implications of climate change, and undertake a comprehensive review of what global climate change will mean for the EU. This will feed into the upcoming 'Integrated threat and risk assessment reports' to be adopted by the Commission and the High Representative (2015).

Action 5: Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe.

The Commission and the EEA will improve access to information and develop interaction between Climate-ADAPT and other relevant platforms, including national and local adaptation portals (2013/2014). Special attention will be given to cost-benefit assessments of different policy experiences and to innovative funding, via closer interaction with regional and local authorities and financial institutions.The inclusion of the future Copernicus climate services will be prepared in 2014.

Climate-proofing EU action: promoting adaptation in key vulnerable sectors

The next priority area is the responsibility for the Commission is to mainstream adaptation measures into EU policies and programmes, as the way to 'climate-proof' EU action. The Strategy highlights that adaptation has already been mainstreamed in legislation in such sectors as marine waters (Council Directive 2008/56/EC and EU Regulation No 1255/2011, forestry (Regulation (EC) 2152/2003), and transport (Decision 661/2010/EC); and in important policy instruments such as inland water (COM(2012)673 final), biodiversity (COM(2011)244 final) and migration and mobility (COM(2011) 743 final and also a working document in the annexes supporting the strategy).

In addition, the Commission has tabled legislative proposals on integrating adaptation in agriculture and forestry)[13], maritime spatial planning and integrated coastal management (COM(2013) 133 final), energy (COM(2011) 665/3, disaster risk prevention and management (COM(2011)934 final), transport (COM(2011) 650/2 final), research, health[14], and the environment (COM(2012) 628 final).

[13] http://ec.europa.eu/agriculture/cap-post-2013/legal-proposals/index_en.htm
[14] http://ec.europa.eu/governance/impact/planned_ia/docs/2013_sanco_002_eu_plant_health_law_en.pdf

These initiatives are **extremely important for a number of case study domains in ECONADAPT, including DRR (WP6), project appraisal (WP7) and especially policy appraisal (WP8).**

The strategy outlines that these moves to mainstream climate change adaptation into EU policies will be pursued in priority fields such as energy and transport. In health policy, most human, animal and plant health measures and systems are already in place, but they need to be adjusted to whatever new challenges climate change will bring. The three Commission staff working documents on health, marine and coastal areas, and infrastructure, which accompany the Strategy (see list above), set out what the Commission is currently doing in this area.

The Strategy also highlights that forthcoming policy initiatives, in areas such as invasive alien species (2013), green infrastructure (2013), land as a resource (2014-15), and a new Forest Strategy (2013) are also expected to consider adaptation. Guidelines on adaptation and coastal zone management are being formulated (2014), and guidelines on adaptation and the Natura 2000 network are shortly to be issued (2013).

The strategy highlights that infrastructure projects, which are characterised by a long life span and high costs, need to withstand the current and future impacts of climate change. Building on the recent mandate to assess the climate change implications for Eurocodes[15], and the Commission's work with standardisation organisations, financial institutions and project managers needs to analyse to what extent standards, technical specifications, codes and safety provisions for physical infrastructure should be strengthened to cope with extreme events and other climate impacts.

Finally, the Strategy outlines that disaster insurance has a generally low market penetration rate at the moment in Member States[16]. Discussions should take place with stakeholders on the basis of the Green Paper on the insurance against natural and man-made disasters.

This latter area has high relevance for WP5.

Action 6: Facilitate the climate-proofing of the Common Agricultural Policy (CAP), the Cohesion Policy and the Common Fisheries Policy (CFP).

Guidance is being provided as part of the Strategy on how to further integrate adaptation under the CAP and the Cohesion Policy. Similar guidance will be issued in 2013 for the CFP. It is aimed at managing authorities and other stakeholders involved in 2014-2020 programme design, development and implementation. Member States and regions can also draw on the 2014-2020 Cohesion Policy and CAP to address the knowledge gaps and invest in the needed analyses, risk assessments, tools and build up capacities for adaptation.

Action 7: Ensuring more resilient infrastructure

In 2013 the Commission will launch a mandate for European standardisation organisations to start mapping industry-relevant standards in the area of energy, transport and buildings, identifying standards to be revised for better inclusion of adaptation considerations. It will also provide with the Strategy guidelines for project developers working on infrastructure and physical assets, with a view to climate-proofing vulnerable investments. Drawing on the results of its Communication on Green Infrastructure, the Commission will in 2013 explore the need for additional guidance for authorities and decision makers, civil society, private

[15] Eurocodes are a set of harmonised technical rules for the structural design of construction works in the EU developed by the European Committee for Standardisation
[16] Joint Research Centre, European Commission (2012), *Natural catastrophes: Risk relevance and insurance coverage in the EU*

business and conservation practitioners to ensure the full mobilisation of ecosystem-based approaches to adaptation.

Action 8: Promote insurance and other financial products for resilient investment and business decisions.

The Green Paper on the insurance of natural and man-made disasters, adopted together with this Strategy, is a first step in encouraging insurers to improve the way they help to manage climate change risks. The Commission's aim is to improve the market penetration of natural disaster insurance and to unleash the full potential of insurance pricing and other financial products for risk-awareness prevention and mitigation and for long-term resilience in investment and business decisions (2014-2015).

In terms of financing, the Strategy highlights that improved access to funding will be a critical factor in building a climate-resilient Europe. The draft 2014-2020 Multi-annual Financial Framework (MFF) includes a proposal for increasing climate-related expenditure (for mitigation and adaptation) to at least 20 % of the EU budget. It is strategically important for such investment to be climate-resilient. Specifically, the Commission has included climate change adaptation in its proposals for all relevant EU finance programmes for 2014-2020. The European Structural and Investment funds (The Cohesion Fund, the European Regional Development Fund (ERDF), the European Social Fund (ESF) the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund (EMFF)) as well as Horizon 2020 and the LIFE programme will provide significant support to Member States, regions and cities to invest in programmes and projects on adaptation, especially in the framework of the dedicated Investment Priorities on adaptation in the ERDF and Cohesion Fund.

Moreover, several EU funds and international financing institutions, such as the European Investment Bank and the European Bank for Reconstruction and Development, also support adaptation measures. The Commission will explore further ways of accommodating some adaptation investment expenditure, such as expenditure co-financed by the EU in the assessment of Stability and Convergence Programmes.

<u>**This implies a very large increase in relevant adaptation flows**</u>.

In addition, the Strategy set out that there are specific funds – including at national level – and public financial institutions that support adaptation action, e.g. on flood control and drought management. Climate-ADAPT will be providing more information on potential sources of funding. Member States can also use EU ETS auction revenues as a source of financial support for adaptation

Finally, the strategy sets out that in 2017 the Commission will report to the European Parliament and the Council on the state of implementation of the Strategy and propose its review if needed.

This timing fits with the ECONADAPT project. <u>**It is likely that the advances made with respect to the evidence base on the costs and benefit of adaptation (in Action 4) will draw heavily on the ECONAPT project. This provides a key opportunity for enhancing the impact of the project.**</u> Additional information from the key annexes to the Strategy are discussed below.

Technical guidance on integrating climate change adaptation in programmes and investments of Cohesion Policy

The purpose of this guidance is to help adaptation experts, Managing Authorities and other stakeholders to ensure that Cohesion Policy programmes and projects address and consider the expected impacts of climate change and take active steps to reduce climate risks.

The 'Cohesion Policy' refers to the three following Funds: the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund (CF). The guidance is mainly aimed at the 2014 – 2020 Cohesion Policy programming period.

It helps to:
• Explain, in simple terms, where the proposed regulations provide opportunities for adaptation and point out how they can be applied at each stage of the programme cycle
• Suggest which types of authorities to approach in each case and what type of information to bring to the process
• Explain what type of information on climate change impacts and adaptation options may be available and when to use it
• Identify, based on practice and experience around the EU, good examples of programmes, projects and approaches from 2007-2013 that integrate adaptation.

The guidance is a manual, containing advice, methods, tips and examples on what to do at each stage to spread the adaptation message and take advantage of legal and policy instruments available to them. In addition, sectoral fiches provide the information base and concrete technical options. The fiches may be useful directly to sectoral authorities, project developers and other interested parties as well.

Methodologies for climate proofing investments and measures under Cohesion and Regional policy and the Common Agricultural Policy (CAP) (Contract No 07.1303/2011/603488/SER/CLIMA.C3) by the Institute for European Environmental Policy (IEEP) together with Ecologic Institute, Milieu, GHK and Environment Agency Austria.

<u>This has high relevance for WP6, project appraisal, and WP7, policy appraisal</u>

Adapting infrastructure to climate change.

This paper presents the contribution of the European Union to climate change adaptation in selected infrastructure sectors. It covers energy and transport infrastructure as well as buildings in the EU – sectors which were given priority for adaptation policy mainstreaming in the 2009 White Paper on Climate Change Adaptation. The paper also discusses the instruments and financing provided by the European Union to make Europe's infrastructure more climate resilient.

<u>This has high relevance for WP6, project appraisal.</u>

Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient.

The **primary objective** of these Guidelines is to help developers of physical assets and infrastructure incorporate resilience to current climate variability and future climate change within their projects. They are aimed at helping project developers understand the steps they can take to make investment projects resilient to climate variability and change. The Guidelines provide information on the steps that can be undertaken to integrate climate resilience within a familiar project lifecycle appraisal practiced by project developers. They explain when and how to apply seven modules which make up the climate resilience toolkit.

The guidelines are targeted at '*Climate-influenced projects'* – assets and infrastructure projects whose success may be affected if climate change is ignored, and '*Climate adaptation projects'* - whose main aim is to reduce vulnerability to climate hazards, such as a flood management scheme.

Step 6 Appraisal of adaptation options (AAO) – is particularly relevant. This is largely based on the earlier UKCIP costing method (2004).

This has high relevance for WP6, project appraisal.

Green paper on the insurance of natural and man-made disasters

The Green Paper poses a number of questions concerning the adequacy and availability of appropriate disaster insurance and accompanies the Communication entitled "An EU strategy on adaptation to climate change". The objective is to raise awareness and to assess whether or not action at EU level could be appropriate or warranted to improve the market for disaster insurance in the European Union. More generally, this process will also expand the knowledge base, help to promote insurance as a tool of disaster management and thus contribute to a shift towards a general culture of disaster risk prevention and mitigation, and bring in further data and information.

This has high relevance for WP5, DRM.

It is also highlighted there is an Adaptation and Disaster Risk Management and background note to the 1st meeting of the Working Group on Adaptation. March 25, 2014 has been produced.

SWD (2013) 139 - Principles and recommendations for integrating climate change adaptation considerations under the 2014-2020 rural development programmes.

This document is intended to ensure that climate adaptation objectives are embedded in the design of their 2014 – 2020 Rural Development Programmes (RDPs).

This has high relevance for WP7, policy appraisal.

Other Key Documents

In addition to the EU 2013 package, a number of other documents are relevant.

The EU Cohesion Policy regulations require a cost-benefit analysis (CBA) of all major investment projects applying for assistance from the Funds (structural and cohesion funds). The **EC Guide to Cost Benefit Analysis of Investment Projects (DG REGIO, 2008)** offers specific guidance for project proponents to conduct a full financial and economic CBA with a view to determine their eligibility for EU grants.

The guidelines are currently being revised and there is some initial information on adaptation appraisal, though this is a very small component at present.

The EC is in the process of finalising Guidance for Integrating Climate Change and Biodiversity into **Environmental Impact Assessment**. The Guidance is aimed at helping publicly and commercially funded projects take into account climate change (and biodiversity) in their EIAs.

In 2010 the EC issued a “Staff **Working Paper on Risk Assessment and Mapping Guidelines for Disaster** Management”. The main aim of the guidelines is to provide coherency across risk assessments and facilitate their undertaking at the national level in EU Member States. The guidelines are based on the ISO Standards and aim at greater transparency and cooperation in efforts to prevent and manage shared risks. Member States have voluntarily committed to perform national risk assessments by the end of 2011 and to further develop national risk assessment approaches.