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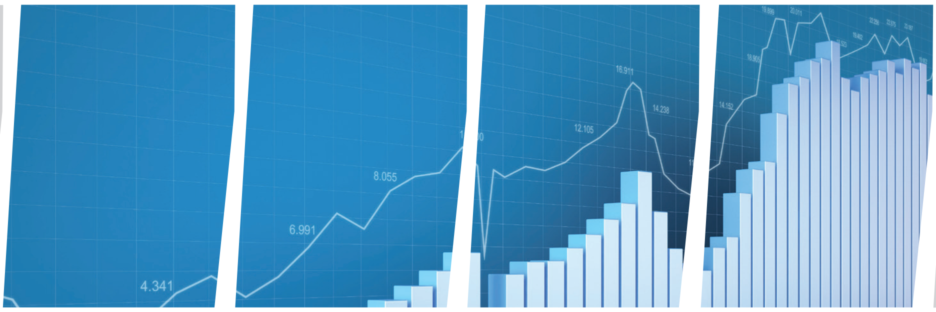

Strategic adaptation to climate change in Europe

Sam Fankhauser, Vivid Economics.

Raluca Soare, Vivid Economics.

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Abstract

This paper analyses the priorities and challenges for Europe as it adapts to the impacts of climate change. Whatever the ultimate level of warming we will experience, adaptation will be a permanent feature of decision making from now on. As such it is important to go about it in a strategic, rational way.

A strategic approach to adaptation involves setting priorities, both spatially (*where* to adapt) and inter-temporally (*when* to adapt). The paper reviews the available evidence on Europe's exposure, sensitivity and adaptive capacity to indicate geographic adaptation priorities. In terms of inter-temporal priorities, it recommends fast-tracking two types of action: Win-win measures that yield an immediate return, such as water efficiency, and strategic decisions on infrastructure and planning that have long-term consequences for Europe's vulnerability profile.

A strategic approach to adaptation involves careful project design to ensure adaptation measures are cost-effective (*how* to adapt). An important complication in this respect is the deep level of uncertainty that still exists about future climate change at the local level. This puts a premium on flexible designs that can be adjusted when new information becomes available.

The final element of a strategic approach to adaptation is division of labour between the state on the one hand, and private actors (households and firms) on the other (*who* should adapt). The paper argues that the traditional functions of the state – the provision of public goods, creation of an enabling environment and protection of the vulnerable – also apply to adaptation.

JEL classification: H12, H43, H84, Q54

Sam Fankhauser, Director at Vivid Economics

Raluca Soare, Analyst at Vivid Economics

Contact us :
306 Macmillan House T: +44 (0) 844 8000 254
Paddington Station E: enquiries@vivideconomics.com
London W2 1FT

1. Introduction

In the intricate vocabulary of climate change policy the term "adaptation" is used to describe measures that deal with the consequences of climate change – the steps taken by coastal communities to protect themselves against rising sea levels, for example. Adaptation is contrasted to mitigation, that is, measures that deal with the causes of climate change and aim to reduce emissions.

Most policy makers would see adaptation and mitigation as complements, in the sense that the optimal response to climate change will include both sets of measures.[1] Yet adaptation has received much less analytical attention than mitigation, and is only now appearing on the radar screen of policy makers. At least this is the case in industrialised countries.

Low-income countries, with their high vulnerability to climate change and often low levels of emissions, have always seen adaptation as a priority. Indeed, much of the adaptation literature is specifically devoted to understanding adaptation in developing countries (*e.g.* Bowen *et al.* 2012; Fankhauser and Burton 2011) and in particular the climate finance needs of developing countries (Fankhauser 2010a, Narain *et al.* 2011, Parry *et al.* 2009, World Bank 2010a). There is a broad consensus that developing countries will be hardest hit by climate change (Parry *et al.* 2007, Wheeler *et al.*2010, World Bank 2010b).

This does not mean that the adaptation challenges of Europe or other industrialised countries should be underestimated. There are areas of high vulnerability also in Europe (Parry *et al.* 2007; PESETA 2009, ESPON 2011) and in an interconnected, globalised world the effects of climate change elsewhere in the world will also be felt in Europe (UK Government Office for Science 2011).

European governments are beginning to wake up to the issue. Since 2005 quite a few climate adaptation strategies have been produced (Swart *et al.* 2009), although they are as yet rather general in scope. Governments are approaching the issue from different directions. Southern Europe has taken a sectoral approach, focusing particularly on water. Central and northern Europe emphasise flooding. Denmark's focus was on adaptation agents, with an emphasis on 'autonomous adaptation' by affected stakeholders. Portugal in contrast is keen on public sector involvement. The plans of Germany, Finland and the UK emphasise the adaptation process and put in place formal procedures for monitoring, reviewing and enforcement.

There is a distinct impression that policy makers are still struggling to make sense of adaptation. On the one hand, adaptation (unlike mitigation) is clearly in the self-interest of people and the human race has proven to be singularly adept at dealing with different climate conditions (Pittock and Jones 2000). It seems natural therefore to see adaptation as something people, in developed societies at least, will do without much help or encouragement.

On the other hand, it is clear that adaptation will be a complex and pervasive task. Our socio-economic structures are finely tuned to the climate we find ourselves in. Adaptation to the current climate is reflected in everything from consumption choices and cultural norms to production techniques and the design of buildings and infrastructure. Adaptation to future climate change will affect many, perhaps most, of these behaviour, consumption and investment decisions.

[1] From a strict economic point of view adaptation and mitigation are probably substitutes, since an increase in the price (or cost) of adaptation is likely to increase the demand for mitigation, all else equal. This is the standard economic definition of substitute goods.

On closer inspection it also becomes apparent that we are not as well adapted to the current climate as one might think. There are instances of maladaptation. The empirical literature on how people adapt in practice has identified multiple market, information and policy failures (Di Falco *et al.* 2010, Hanemann 2008; Sobel and Leeson 2006; Noy 2009, ASC 2011).

The conceptual literature contains several methodologies and "how to" manuals for adaptation practitioners (Ranger *et al.* 2010; Swiss Re 2009; ASC 2010; Parry and Carter 1998; Carter *et al.* 1994). They offer important pointers for practitioners on how to devise a sensible adaptation framework. Yet, there is a need to adopt a more rational, strategic approach to the problem. Many climate change assessments to date have aimed at producing a comprehensive inventory of climate risks (DEFRA 2012). This is impossibly ambitious. The purpose of an adaptation plan cannot be to produce a complete blueprint for future adaptive action. Rather it should highlight areas of likely risk, establish priority responses and set the principles of good adaptation.

To make headway on a more strategic approach to adaptation it is worth remembering what basic welfare economics teaches us on issues such as risk management, project appraisal, market failures and intertemporal optimisation. Public economics can inform on the role of the state and the extent to which adaptation is a public policy issue.

The purpose of this paper is to apply these basic principles to adaptation in Europe. The aim is not to produce yet another adaptation method, but to explore four basic questions that are at the centre of a strategic approach to adaptation:

- ***Where to adapt:*** Where are the key climate change risks and vulnerabilities? What should therefore be the geographical and sector priorities for adaptation?
- ***When to adapt***: Given that climate change is a long-term issue, how can adaptation be sequenced? What type of activities needs to be initiated now?
- ***How to adapt***: How should good adaptation projects be designed to be neither over- nor underspecified? How can adaptation respond to the high degree of uncertainty about future climate risks?
- ***Who should adapt***: To what extent will adaptation be undertaken autonomously by the private sector? To what extent will private adaptation be hindered by policy, market and information barriers, and what is therefore the role of the state?

The paper deals with each of these questions in turn, outlining both the methodological approach and suggesting a high-level answer for adaptation in the European Union.

2. Where to adapt Europe's vulnerability

The first step in a strategic approach to adaptation is to develop an understanding of the main areas of vulnerability to climate change. A broad sense of the main vulnerabilities will help policy makers to set the right sector and geographic priorities.

Developing this sense of key vulnerabilities is not the same as adopting a science-first approach to adaptation (Ranger *et al.* 2010). A science-first analysis would start with a study of the possible climate change outcomes and quantify in some detail the likely effects of climate change under each different scenario. The need for adaptation would then follow from the nature of these effects (see *e.g.* World Bank 2010a).

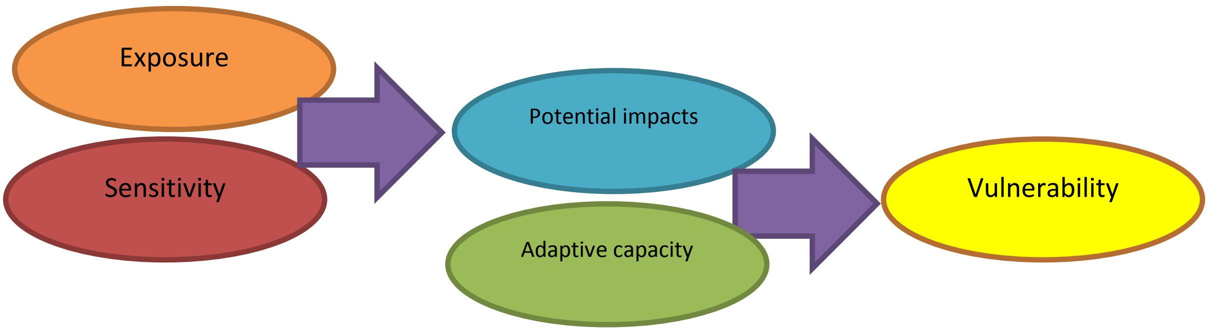
While science-first is the method of choice for impact assessments, it raises issues for adaptation analysis. First, it may lead analysts to underestimate the level of uncertainty. Given the analytical effort involved in developing local climate scenarios, studies typically have to restrict themselves to a small number of scenarios for which adaptation measures are fine-tuned. However, rational adaptation decisions will have to account for the full range of possible climate outcomes and not just one particular scenario. Second, there are problems with the timeframe. Most "science-first" studies focus on the period 2050-2100 for which climate models give the clearest results. However, the timeframe for adaptation decisions is rarely more than 10-20 years. Third, with the bulk of the effort devoted to getting the climate scenarios right, insufficient attention is paid to the actual adaptation decisions and the institutional, regulatory and economic context in which they are made.

Ranger *et al.* (2010) therefore advocate a "policy-first" approach that puts adaptation decisions at the centre of the analysis. Their approach starts with the current situation, that is, the procedures that are in place to deal with the current climate and asks how they might have to change. It explicitly deals with uncertainty by designing adaptation measures that are rational in light of our limited understanding of potential outcomes.

However, even under a "policy-first" approach it is important to develop at the outset a broad sense of the main areas of vulnerability. There is a difference between assessing climate change impacts and climate change vulnerability. This is explained in Figure 1. Vulnerability to climate change is a function of the potential impacts and the capacity of a society or system to adapt. The potential impacts are in turn determined by the system's exposure and its sensitivity. That is, an assessment of climate vulnerabilities is broader than an impact assessment. It also takes into account the capacity to adapt.

Existing indicators of climate vulnerability in Europe (*e.g.*, DARA 2010) suggest that over the next 20 years Europe might experience both increases (*e.g.* in Hungary, Slovakia and Spain) and decreases in vulnerability (*e.g.* in Denmark, Ireland, Lithuania and the UK). In the remainder of this section we use readily-available information on exposure, sensitivity and adaptive capacity in Europe to develop a high-level sense of what some of the main areas of vulnerability in Europe might be.

Figure 1. Vulnerability is a function of exposure, sensitivity and adaptive capacity



Note: Exposure refers to the climate stimuli impacting upon a system (for example the amount of warming observed). Sensitivity refers to the degree to which the system is affected by changes in climatic inputs (for example, the share of GDP in climate-exposed sectors like agriculture). Adaptive capacity refers to the ability of a system to deal with the new external stimuli (for example, the quality of emergency services in a country).

Source: IPCC.

2.1 Exposure

A picture of Europe's exposure to climate change can be drawn from various impact studies (*e.g.*, Parry *et al.* 2007, PESETA 2009, ESPON 2011). They suggest that, in terms of ***temperature,*** and dependent on the emission scenario, Europe may see a rise in annual temperature of 0.1 to 0.4°C per decade to 2100, with warming greatest over Eastern Europe in winter and over western and southern Europe in summer. Northern Europe will benefit from a more temperate climate, whereas Southern Europe (and the Mediterranean region in particular) will experience a hotter climate. As an illustration, for a mean temperature increase of 2.5°C (expected by 2080), temperatures may increase by 1 to 2°C in the British Isles and small north-western fringes in France and Spain, whereas in the very northern part of Scandinavia, Finland, parts of central Spain, the temperature rise could exceed 3 °C (PESETA 2009).

For all emission scenarios, mean annual ***precipitation*** generally increases in northern Europe and decreases further south, with substantial variation in seasonal precipitation across seasons and regions. Annual runoff is expected to increase in Atlantic and northern Europe, and decrease in the Mediterranean. There may be an increase in winter flows and decrease in summer flows in the Rhine, the Volga and Central and Eastern Europe. The duration of snow cover at middle elevation in the Alps is expected to decrease by several weeks for each degree of warming.

In terms of ***sea level rise*** scenarios predict the inland migration of beaches, increased salinization of ground water and the loss of up to 20 percent of coastal wetlands. Low-lying coastlines with high population densities and small tidal ranges, such as the southern North Sea and coastal plains/deltas of the Mediterranean, Caspian and Black Seas are most exposed.

There are likely to be more ***extreme weather events.*** Warmer, drier conditions in the Mediterranean are likely to result in more frequent and prolonged droughts, heat waves, a longer wildfire season and increased fire risk. Winter floods are likely to increase in maritime regions. Flash floods are likely to increase throughout Europe, in particular in major river basins such as the Loire, Garonne and Rhone in France, the Po in Italy and the Danube in Central and Eastern Europe.[2] Countries in central Europe may experience the same number of hot days as currently occur in southern Europe (Beniston *et al.* 2007).

2.2 Sensitivity

Sensitivity to climate events is a function of economic structure (*e.g.* reliance on sectors like agriculture), environmental management (*e.g.*, the baseline stress put on the natural environment) and bio-physiological factors (acclimatisation, age of population). We may thus distinguish between economic, environmental and societal sensitivity.

In terms of ***economic sensitivity***, countries with an important agricultural sector (*e.g.* Romania, Greece, Slovakia, Slovenia, Italy, and France) will, all else equal, be more affected by climate change. The sign of the effect depends on the type of exposure. Crop productivity is projected to increase in northern Europe, but may fall elsewhere (Parry *et al.*, 2007). Northern European countries with an important forestry and logging sector (*e.g.* Finland, Estonia, Latvia, Sweden) may also benefit as forests are projected to expand in northern Europe and retreat in the south (Parry *et al.* 2007).

Another sector that is sensitive to climate change is tourism (PESETA 2009). The Alpine region and the Mediterranean are two major touristic hotspots that are also exposed to

[2] See http://floods.jrc.ec.europa.eu/climate-change-impact-assessment/floods.html

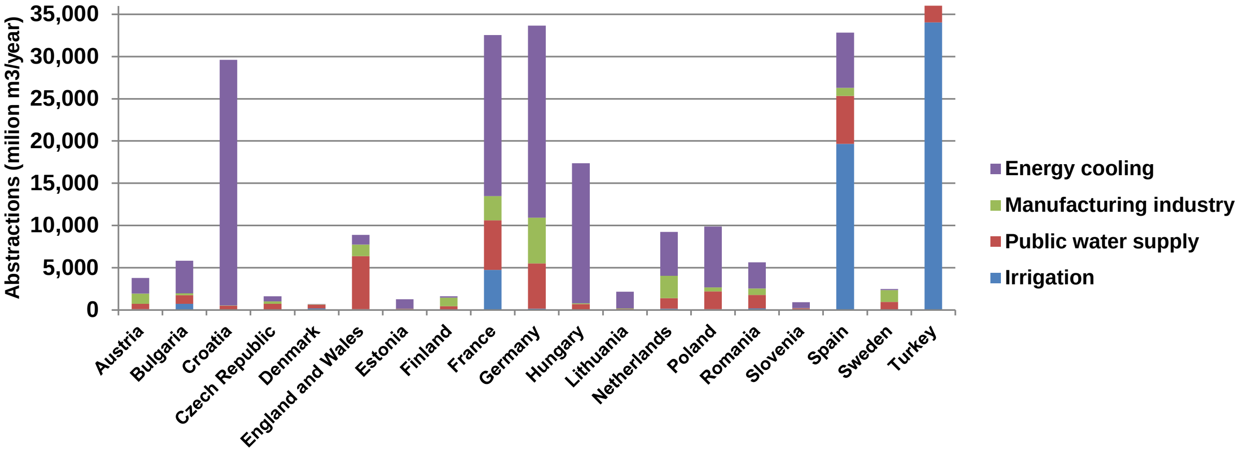
climate change (ESPON 2011). In terms of gross value added, the countries with the biggest tourism industries in these regions, and thus the highest sensitivity, are Spain, Greece, Austria, Italy and France. Overall, the top five[3] tourist destinations in Europe, ranked by number of tourists, are Germany, France, the UK, Italy and Spain.

Note that sensitivity may be both direct (*e.g.* via crop productivity for farmers) and indirect (*e.g.* through higher crop prices for agribusiness and consumers). Sensitivity in the latter sense is harder to ascertain as it depends on economic structure, market dynamics, and internal and external trade patterns. The EU's open market will allow the impacts of climate change to spread more easily than would otherwise be the case, although that will also help to smooth the localised effects of climate change (see section 2.3).

One of the most important aspects of ***societal sensitivity*** is demographic trends, and in particular Europe's ageing population. Older people tend to be more sensitive to extreme weather events and often have a lower adaptive capacity (see below). Other factors that may affect sensitivity include migration patterns (*e.g.* towards or away from risk zones like coasts), public health issues, cultural habits and urbanisation, although the relative sensitivity of urban and rural areas is still poorly understood.

A key issue in terms of ***environmental sensitivity*** is water use, although there are broader concerns related to environmental mismanagement, including pollution (which can be exacerbated by climate conditions) and the overuse of natural resources, such as fish stock. High water stress areas are expected to increase from 19 percent in 2009 to 35 percent by the 2070s (European Commission, 2009). The level of water extraction, relative to resources, varies, but is particularly high in Mediterranean countries (*e.g.*, Croatia, France, Spain, Turkey), where climate change is expected to lead to a fall in precipitation (see Figure 2). Over 80 percent of European agriculture is rain-fed (European Commission, 2009), but irrigation uses a large part of water resources in Spain, Greece and Portugal. France and Hungary also have a high need for cooling water in their electricity sectors. The risks this may create were illustrated by the heat wave of 2003, when a lack of cooling water affected nuclear energy output in Germany and France.

Figure 2. Water abstractions for different uses (2007 or latest available year)



Note: Countries with incomplete or missing data are not included in the graph (*e.g.* Ireland, Portugal)
Source: Eurostat's Annual water abstraction by source and by sector

[3] based on EUROSTAT 2010 data (2009 for Italy)

2.3 *Adaptive capacity*

Adaptive capacity, or the ability to respond to climate stress, is difficult to quantify. There is a strand of literature that aims to understand adaptive capacity at a global level (Barr *et al.* 2010, Tol and Yohe 2007; Noy 2009). It identifies factors such as income inequality, per capita income, the level of education, access to finance and insurance, and the quality of institutions as key determinants of adaptive capacity.

There are also methods to determine adaptive capacity at the level of an institution. The UK climate change risk assessment (DEFRA 2012), for instance, used a tool called PACT (Performance Acceleration for Climate Tool) which focuses on "organisational capacity pathways" such as awareness of climate change, leadership, systems of reporting, the skills of individuals, the ability to learn and innovate and the ability to engage with other stakeholders. PACT has also been used for reviewing the Dutch Government's National Adaptation Strategy.[4]

It is hard to draw firm conclusions from the existing literature on adaptive capacity in Europe. Institutional assessments are too few to allow a credible extrapolation, while the global studies are not granular enough to determine differences in adaptive capacity among advanced countries. Most of them have uniformly high scores for aggregate indicators like education and institutional strength.

Nevertheless, the available evidence would probably suggest that there are differentials in adaptive capacity between Northern Europe on the one hand and southern and central Europe on the other. Adaptive capacity is strongly correlated with income, and it is therefore a reasonable conjecture that it will be lower in the southern and eastern parts of Europe.

The literature on adaptive capacity also implies that the EU's ability to adapt may be enhanced by some of the fundamentals for which the Union stands: free trade and the mobility of capital and labour. According to Bowen *et al.* (2012), trade and mobility in input factors can help to smooth the impacts of localised climate events. However, ultimately, adaptive capacity is a local or perhaps national issue.

Table 1 gives an example of national variation in adaptive capacity: France's response to the 2003 heat wave compared with Greece's response to the 2007 wildfires. Neither country was particularly well-prepared at the time of the disaster, but France subsequently set out to improve its ability to respond by developing an early warning system that has served as an example to many other countries. Greece was much slower in addressing institutional shortcomings, and as a result found itself once again vulnerable when the problem reappeared in 2009.

[4] See http://www.pact.co/pact_in_use

Table 1 France's swift response to the heat wave of 2003 enhanced its adaptive capacity, whereas Greece's mismanagement of the 2007 wildfires left it vulnerable to future extreme weather events

	France	Greece
Identified vulnerability	**Heat wave** of summer 2003 – warmest ever August recorded in the northern hemisphere resulted in a death toll in France of over 14,800 (out of 35,000 in Europe as a whole)	**Wildfires** of 2007 – most catastrophic in the country's history, claiming more than 70 lives, 270,000 ha of forest, olive groves and farmland, entire villages and infrastructure
Response (aftermath)	Heat Health Watch Warning System (HHWWS) developed on the basis of retrospective analysis of meteorological and mortality data collected from 14 pilot cities. After testing for sensitivity and specificity, an indicator that mixes max (day) and min (night) temperatures was chosen. HHWWS is integrated in the **national action plan** as follows: . Level 1 (watch): seasonal vigilance system from 1st June to 30th September; . Level 2 (warning): thresholds are to be reached within three days; . Level 3: thresholds are reached; . Level 4: thresholds are reached and exceptional circumstances (*e.g.* drought, electricity blackout, heat wave is prolonged).	More heavy lift helicopters were contracted, but little was done about fundamental problems in forest fire management. Following institutional restructuring in the late 1990s, competence for forest fire suppression was transferred from the Forest Service (FS) to the Greek Fire Service (GFS) causing resentment among FS personnel. No provision was made for adequate cooperation between the FS and GFS. The decision resulted in a shift in emphasis from forest fire prevention to fire suppression. The GFS' strength and preferred operational method is air attack, however, on ground activity, which is equally, if not more important, the GFS lacks the training and the specialised knowledge of forests that the FS has.
Outcome (in terms of adaptive capacity)	When the next heat wave hit France in 2006, the number of excess deaths was close to 2000 people, well below the estimated rate of c.6400 (estimation based on 1975-2003 meteorological statistics and mortality rates). Although other factors may have influenced this result, it is likely that the HHWWS played an important role (INSERM 2006).	When wildfires occurred again in 2008 and 2009, Greece had to request help from other countries. Early warnings were not given full consideration. Institutional barriers (*e.g.* on forest property rights*, coordination and cooperation between services) remain.

Note: * Some of the fires were caused by arson. In Greece regulations on burned forest land are not enforced and property rights are a problem; as a result people sometimes burn forest areas in order to claim the land and build houses on it.

Source: Pascal *et al.* 2006, INSERM 2006; European Parliament's 2008 Study on forest fires, Tsaliki 2010, Xanthopoulos 2011

3. When to adapt: Adaptation timing

There is evidence that some impacts of climate change can already be felt today (*e.g.* possibly the increase in wildfires in Greece, Portugal and Italy, drier and hotter summers in the Mediterranean). Nevertheless, the most severe effects are not expected to become manifest for several decades. Climate change is a long-term problem. The speed with which adaptation measures are initiated and ramped up is therefore an important policy decision.

The theory of adaptation timing has been set out in Fankhauser *et al.* (1999). Basic economic theory suggests that delaying investment in adaptation could make sense. The benefits of adaptation will generally occur in the future and if the same future benefits can be realised with later investments, the net present value of the investment would be higher. However, when comparing the net present value of two adaptation strategies – one where adaptation occurs early and one where it is delayed – Fankhauser *et al.* find two cases where it may make sense to deviate from this rule:

- ***Early benefits***: Fast-tracking adaptation makes sense if the proposed measures have immediate benefits that would be otherwise be forgone. These early benefits could for example be related to the management of current climate variability, efforts to reduce greenhouse gas emissions (mitigation) or the removal of broader market and policy failures.

- ***Costly lock-in***: Fast-tracking adaptation is also desirable if acting today costs less than acting tomorrow, even when taking discounting into account. This may happen if today's decisions lock society into a particular development or infrastructure path that would be costly to reverse in the future.

We explore each of these in turn.

3.1 Early benefits

Win-win measures that simultaneously reduce vulnerability to climate change and advance current development objectives are perhaps the most important adaptation measure in developing countries (*e.g.* Fankhauser and Burton, 2011; World Bank 2010a, b). However, even in advanced economies there are adaptations that yield immediate benefits.

There are not many studies that systematically evaluate a wide set of adaptation options in terms of their benefits and costs. Two recent examples are Swiss Re (2009) and ASC (2011). Both use adaptation cost curves, an approach that was inspired by the marginal abatement costs literature and is ultimately no more than a concise way of presenting benefit-cost information. At its core is cost-benefit analysis.

Although ASC (2011) in particular reasserts that developed societies are fairly well adapted to the current climate they find substantial scope for adaptations that would be economically attractive even in the absence of climate change. Others have side benefits in terms of mitigation. Examples of such no-regrets adaptations include:

- Improvements in ***water efficiency***, which would help to ease both current and future pressure on water resources. As shown in section 2 many European regions have high water abstraction rates and would be sensitive to a reduction in water availability. However, according to one study 20-40% of Europe's water is wasted and a 40% increase in efficiency is possible through known technological improvements (Ecologic, 2007). Commercial water losses vary from 6.5 percent in Germany to 28.5 percent in Italy (VEWA 2010). ASC (2011) identifies a number of attractive measures for residential water efficiency, such as low-flow taps, showers and toilets that are cost-effective when installed as part of an end-of-life replacement and may be mandated for new buildings. Efficiency improvements in hot water use would have important emission reduction benefits. A substantial part of domestic energy is used to heat water.

- ***Flood protection*** measures either at the community or buildings level. For the latter, options include airbrick covers, door-guards, repointing of walls, drainage bungs and non-return valves, which ASC (2011) found to be cost-effective either as part of a wider renovation or in new buildings. Flood protection at the community level, even if cost-effective, can be expensive. The EIB has extended substantial loans to repair or improve flood defences in the Czech Republic (€381.8m),[5] Germany (€110m)[6] and Italy (€116.4m)[7] for example.[8] In addition, loans have been provided for post-disaster

5 Loan of €60m in 2001 for flood prevention, and a loan of €312.8m in 2006 for "Prevention schemes throughout Czech Republic implementing National Strategy for Protection against floods"

6 Loan given in 2002 for the "Construction of multi-purpose flood barrier on lower Ems river in north-west Germany"

7 Loans given in 2002 for the "Reconstruction of infrastructure and flood protection in Tuscany, Valle d'Aosta and Piedmont, regions affected by floods in Autumn 2000"

8 See http://www.eib.org/about/publications/annual-report-2010-activity.htm

reconstruction. For example, Poland received €730m for flood damage reconstruction,[9] and the Czech Republic €1,011m.[10] According to Britain's National Audit Office, the annual spend on flood defences in the UK reached £664m in 2010/11 (NAO 2011). However, there are also cheap organisational measures that can improve flood risk management, such as awareness campaigns for local residents (*e.g.*, risk profiles for individual homes, Swiss Re 2009) and improved emergency response training.

- Measures to deal with ***heat stress.*** The 2003 heat wave revealed shortcomings in heat management plans across Europe. Many of the response systems have since been upgraded, but better preparedness for heat waves can potentially be cost-effective. France, which suffered the highest casualty rates in 2003, has introduced a sophisticated new Heat Health Watch Warning System (Pascal *et al.* 2006), which is now replicated elsewhere (Auld, 2008; see Table 1). In buildings, additional no-regrets measures include window shading and investment in energy-efficient appliances that produce less waste heat (ASC 2011). The latter measure could again yield important side-benefits in terms of reducing carbon emissions.

- Protection and better ***management of environmental resources***, as healthy ecosystems are more resilient and better able to adapt to climate stress. The management of European fish stocks is an obvious case in point but there are also terrestrial examples, for instance related to agricultural practices. In areas like the North Sea, the Baltic Sea and the Celtic-Biscay Shelf fish catch is well above the maximum sustainable yield (Worm *et al.* 2009). This is a problem in its own right, but will also compound the effect of climate change on fish stock and fisheries (*e.g.*, Parry *et al.* 2007 and references cited therein).

This list is not exhaustive, but it illustrates the scope for adaptation measures that address both current policy issues and future climate risks.

3.2 Costly lock-in

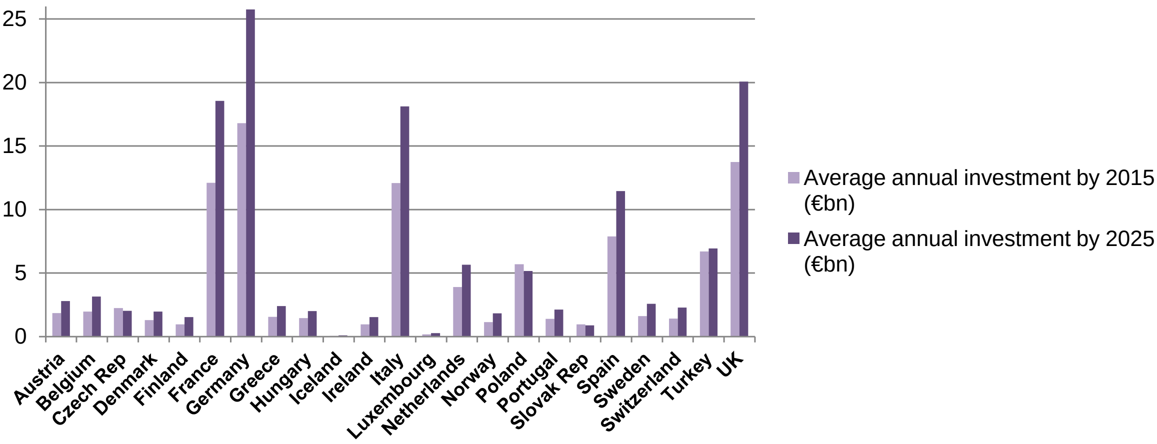
Many decisions taken today have the potential to affect our vulnerability profile for decades. For these strategically important decisions it is important to factor in adaptation concerns right now. The most obvious cases are (Agrawala and Fankhauser 2008, ASC 2010; Fankhauser *et al.* 1999):

- Long-lived ***infrastructure investments*** such as ports, roads, water supply systems, but also flood protection schemes and coastal defences. These structures are both sensitive to the impacts of climate change and sufficiently long-lived to experience change during their economic life. The infrastructure needs in Europe are expected to cost trillions of euros over the coming decades (Siemens Financial Services 2007). Figure 3 illustrates this for the annual water investments needed out to 2015 and 2025. Not all of these investments are sensitive to climate change, but early studies suggest that the cost of "climate-proofing" that fraction that is could add 5-20% to the capital cost of these investments. It is worth noting, though, that these numbers are at best illustrative guesstimates (Fankhauser 2010b; Agrawala and Fankhauser 2008).

[9] Loan of €300m approved in 1997 for rebuilding infrastructure damaged in the summer floods in south and south-west Poland (see http://www.europolitics.info/eib-loan-for-flood-damage-reconstruction-in-poland-artr162226-44.html for more details), loan of €250m given in 2001 for "Emergency aid programme for reconstruction and repair of infrastructure following floods of July 2001", and a more recent loan of €180m in 2011 for the reconstruction of roads damaged by floods in 2010 (EIB, 2012)

[10] Private communication from EIB, March 2012 – a loan of €392.3m in 2009 for flood damage reconstruction, €80m in 2002 for the reconstruction of the Prague metro after flood damage, a further €339 the same year for further flood damage reconstruction, and €200 in 1997 for flood damage reconstruction.

Figure 3. Projected average annual expenditures on water and wastewater infrastructure, selected countries



Note: Original data in USD, converted to euros at the average of 2011 quarterly exchange rates
Source OECD Infrastructure to 2030 (OECD, 2006)

- A similar story holds for the design of ***buildings***, which are similarly long-lived. While some adaptive measures can be retrofitted cost-effectively (*e.g.*, to save water, see above), others are best incorporated into the design of the building. [11] In 2010 more than 1.5million housing permits were issued in the EU,[12] and construction started on close to 1 million homes[13] (EMF HYPOSTAT 2010).

- A third category of strategically important decisions is ***planning***, in particular whether or not to allow further economic development in potential hazard zones such as flood plains, coastal areas and regions susceptible to water stress. Such decisions are common and they involve climate risks. The ASC (2011) found increased development in flood risk areas in eight of the nine UK localities studied, and along eroding coast lines in three of the four coastal communities studied.

Proactive adaptation of this kind is not just an issue for national governments. The European Union invests in strategic projects across the region through its Structural and Cohesion funds. For the period 2007-2013, €347 billion were set aside,[14] complemented by an additional €160 billion from national public and private co-financing (European Commission 2007). In 2009, European financial institutions such as the EIB and EBRD lent €5.8 billion to the infrastructure sector. It is paramount that these investments are designed to avoid future climate risks. Recognising this, the EU White Paper on Adaptation calls for "*infrastructure projects which receive EU funding [to] take climate-proofing into account*" (European Commission 2009).

How climate risks are best taken into account is not straightforward. Concern about climate change does not imply foregoing all developments in risk areas, for example. If combined with appropriate defensive investment (such as flood protection) they may well be justified.

[11] The same argument holds for the energy efficiency of buildings. This is another example where adaptation and mitigation concerns go hand in hand.

[12] 2010 for most countries, and latest available data for Italy (2008) and Latvia (2009). No data available for the UK

[13] Data for 2010 available only for 13 out of 27 countries: Belgium, Czech Rep, Denmark, Finland, France, Greece, Ireland, Poland, Slovakia, Slovenia, Spain, Sweden, the UK

[14] That represents more than one third of the EU budget for the period (Ballu *et al.* 2010)

However, it implies thoughtful decision making that carefully weighs up development benefits, adaptation costs and climate risks. In the Netherlands, the Delta Commissie (2008) therefore recommends a cost-benefit analysis for new urban developments in low-lying flood-prone areas. The UK Green Book on public project appraisal also contains guidelines on adaptation. Overall, however, there is still considerable scope to improve decision making and ensure adaptation is taken into account (Sveiven 2010). We turn to this issue next.

4. How to adapt: Good adaptation projects

It is easy to maladapt. The careful design and thorough appraisal of adaptation projects are therefore important. A priori the economic assessment of adaptation projects should be no different from the appraisal of other investments. A well-established set of tools is available to ascertain the value-for-money of adaptation investments, both from a societal (economic) and investors (financial) point of view, including cost-benefit analysis and cost-effectiveness analysis (see *e.g.*, Layard and Glaister 1994).

However, identifying rational adaptation options usually requires more than simple cost-benefit analysis. The reason for this is uncertainty. There is broad agreement among scientists about the basic physics of climate change. This consensus provides the basis for action to curb greenhouse gas emissions. However, there is still considerable uncertainty about the climatic changes that can be expected at the local level. Decision makers seeking to adapt have high demands on the type of climate information they would ideally need. They need to know much more than just global mean temperature on which there are modelling results. They need to know climatic trends at a localised level, not just about temperature, but for precipitation, flood probabilities, wind speeds and much else. In addition to mean changes they need to know seasonal patterns, daily fluctuations and changes in extremes.

Climate models cannot yet produce credible information at this level, although the science is improving (see for example the discussion around the UK's Climate Projections of 2009; Stainforth 2010). Adaptation decisions are therefore inherently made under uncertainty; some would say deep uncertainty or ambiguity (Millner *et al.* 2010). This section discusses the tools available to decision makers faced with this level of uncertainty and provides examples of good adaptation decisions in Europe. We start with a brief review of the evidence from conventional cost-benefit analysis.

4.1 The costs and benefits of adaptation

Our understanding of the costs and benefits of adaptation is still patchy. A small number of studies have sought to ascertain the aggregate global cost of adaptation (World Bank 2010a, Narain *et al.* 2011; UNFCCC 2007), much of it of doubtful quality (Parry *et al.* 2009; Fankhauser 2010a). Of more value are the results of case studies, although that information is concentrated in a few sectors. Outside coastal zones and agriculture our knowledge base is still limited (Agrawala and Fankhauser 2008).

From the available evidence it is clear, though, that adaptation can potentially have high benefit-cost ratios. In agriculture there is evidence from many sources that low-cost adaptation measures like changes in planting dates, cultivars, fertilizer use and management practices will be able, when the time comes, to reduce the effect of climate change on crop yields by often more than half.

Coastal protection is more urgent (see section 3.2) and one of the few sectors where adaptation costs (usually sea walls and beach nourishment) and adaptation benefits (avoided land loss, flooding) are routinely compared. The resulting benefit-cost ratios are not always reported, but a recent study on coastal protection in the European Union suggests benefit / cost ratios of 1.1 – 2.6 by 2020, rising to 4.3- 6.5 by 2080 (Commission of the European Communities 2007).

In the health sector, the UNFCCC has estimated that preventing some 133 million climate-related deaths from malaria, malnutrition and diarrhoea would cost around \$3.8 – 4.4 billion, or less than \$33 per life saved (UNFCCC 2007).

Since these studies focus on some of the most obvious low-regrets measures the high benefit / cost ratios are not unexpected. The question is how the return on adaptation changes as we move up the adaptation 'merit order', that is as we move from 'no regrets' to higher cost adaptation measures. Two recent studies that aim to create adaptation cost curves show that there are potential adaptation measures that would fail the cost-benefit test (Swiss Re 2009; ASC 2011). However, both studies suggest a considerable scope for no-regret adaptations, including improvements in residential water efficiency, better flood risk management, measures to avoid overheating in buildings and better insurance cover. Like the fight against malaria and malnutrition, these are measures that ought to be pursued now (see section 3.1 above). Since they make sense independently of the expected climate change scenario they can be pursued without the need for complex uncertainty analysis. However for other priority investments this is essential.

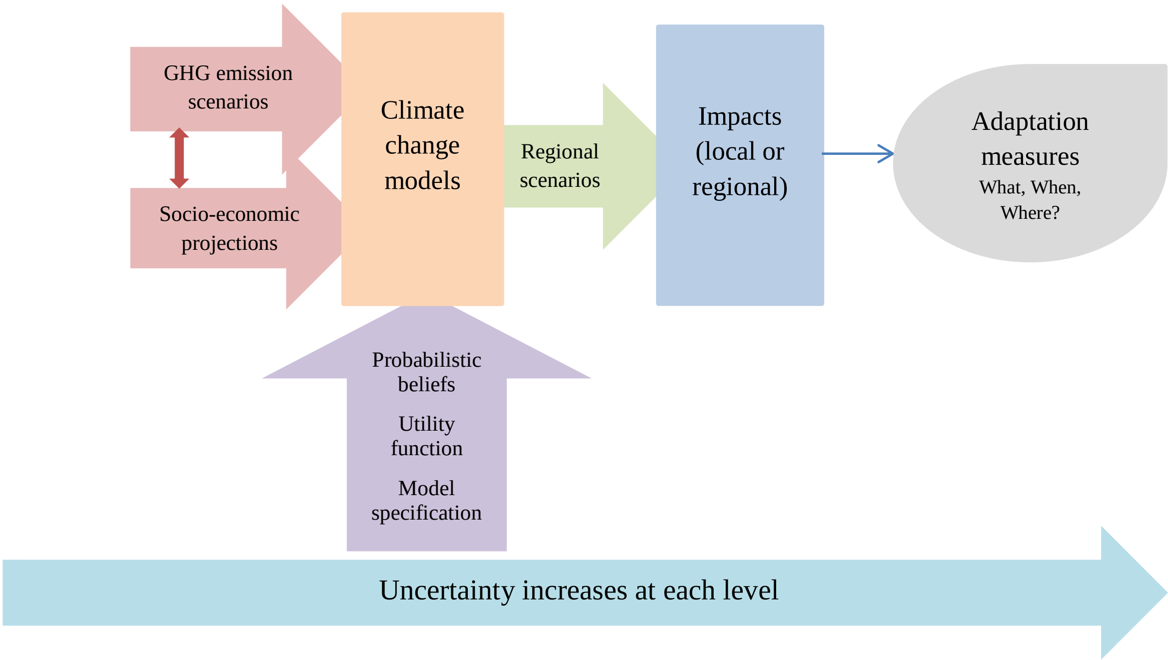
4.2 Accounting for uncertainty

The projected impacts of climate change are broad and as yet still ill-understood. The uncertainty surrounding climate change is compounded at many levels, starting from forecasts of long-term socio-economic projections, to the actual model specification (utility and damage function, parameterisation, omitted variables), to disaggregated regional or local impacts. Figure 4 is an illustration of the compounding uncertainty inherent to climate change modelling. There is endogeneity between the different steps, their uncertainties impacting on each other (*e.g.* GHG emissions and socio-economic projections are interdependent).

As Dessai *et al.* (2009) note, "*limits to climate prediction should not be interpreted as limits to adaptation*". The question is how adaptation decisions can be made in the face of uncertainty. Several decision making methods are available, some applicable to cases where probabilities are known and some to instances when probabilities are not known (see Table 2).

Expected value and expected utility maximisation are the standard tools if the set of possible climate outcomes can be quantified and their probabilities are known. Scientists have used ensemble forecasting (the distribution of results from several climate models and model runs) to approximate impact probabilities, thus potentially enabling the use of these standard tools. However, the approach is not without its critics, with some scientists doubting the validity of the probabilities (see Stainforth 2010, Stainforth .*et al* 2007). They would prefer the use of non-probabilistic approaches like maximin, which focuses on the worst possible outcome, or info-gap decision theory, which emphasises the robustness of a decision. Even if the probabilities are known, some analysts would question whether all impacts can be fully monetised and would thus prefer multi-criteria analysis over expected value approaches. Option theory becomes relevant if there is learning and the true state of nature is eventually revealed.

Figure 4. Uncertainty about climate change is compounded at every level



Source: Vivid Economics based on Ranger *et al.* 2010

While the theory of decision making under climate change uncertainty is complex, there are some straightforward practical implications that are widely agreed. The important message coming from the literature is that adaptation measures should be flexible (*i.e.* they should allow for revision at a later date, decision makers benefitting from information acquired through the years). Adaptation measures should also be robust to a wider range of climate scenarios (Fankhauser *et al.* 1999).

Flexibility intuitively means emphasis on behavioural and regulatory, rather than structural measures. A standard example is the superiority of water demand management and measures to reduce inefficiencies and leakage over investment in new supply infrastructure. Similarly, trade openness, labour mobility and the free flow of capital – three key objectives of European integration – can increase the flexibility of economic systems and their ability to respond to climatic shocks, although openness can sometimes also amplify shocks, for example if it leads to capital outflows (Bowen *et al.* 2012).

Even in the case structural measures it is possible to maintain a degree of flexibility and keep options open. Box 1 provides examples from the Netherlands and the UK. Despite their differences, both showcase how it is possible to maintain flexibility in the face of climate uncertainty.

Table 2. Decision making methods

Decision method	Decision criteria	Preference assumptions	Information assumptions	Additional requirements
Methods applicable when probabilities are known				
Maximise expected value	Economic costs and benefits	Time discounting Risk neutrality Does not account for outcome equity	Known probabilities over all future events No learning	Marginal costs and benefits, *i.e.* small relative to consumption
Maximise expected utility	Broad definition of consumption – including monetised valuations of non-monetary impacts	Time discounting Utility function – accounts for risk aversion and equity of outcomes	As above	
Multi-attribute utility theory and Multi-criteria decision analysis	Many criteria, including non-monetary impacts	As for expected utility + assumptions about interactions between criteria (*e.g.* independence)		
Quasi-option value and Real option analysis	As for expected utility or expected value	As for expected utility or expected value		
Methods applicable when probabilities are not known				
Maximin expected utility	As for expected utility	As for expected utility + extreme ambiguity aversion (act as if the worst plausible probability distribution were correct)		
Smooth ambiguity model	As for expected utility	As above, but allows for any attitude to ambiguity		
Maximin	Any	Ordinal ranking of outcomes	No likelihood information	
Minimax regret	Any	Cardinal ranking of outcomes	As above	
Info-gap decision theory	Various	Does not rigorously account for preferences Assumes satisficing thresholds*	A 'best guess' model of the decision environment, and a set of models that are 'close' to this best guess	A method for measuring the distance between different models (an 'uncertainty model')

* A satisficing threshold (*i.e.* acceptable levels of minimum performance/maximum windfall) is the value of a decision criterion at which an adaptation option is considered good enough

Source: Ranger *et al.* 2010

Box 1 Decisions making under uncertainty in practice – Thames Estuary (TE2100) in the UK and the Delta Commission in the Netherlands.

The Thames Estuary (TE) 2100 project in the UK considered the impacts of sea level rise – storm surges in particular – on London and the Thames Estuary as part of a wider strategy to address flood risk. The project adopted an option-value approach to analyse the consequences of long-lived decisions involving high sunk costs.

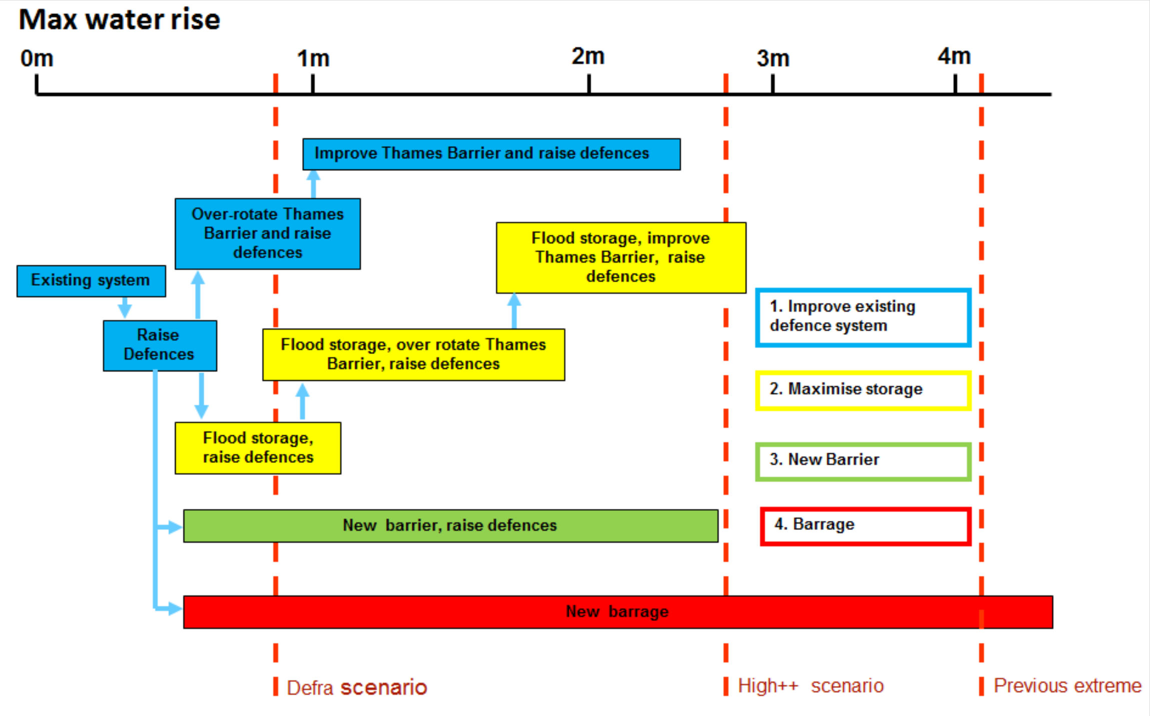
The route-map for TE2100 assigns adaptation options at various decision points. Four packages of measures were designed for various water level rise scenarios, spanning the estimated plausible range. For example, under the ‘most probable’ scenario (*i.e.* water level rise of up to 2.3m), to start with existing defences would be raised, then the Thames Barrier would be over-rotated and defences further raised, culminating in improvements in the barrier and further raising of defences. If the water rises more than 2.3m, flood storage options would also be considered. If monitoring and further research reveals the ‘worst case’ scenario (*i.e.* water level rise of 4.2m) will materialise, then a new barrage would need to be constructed (see 0).

The analysis found that, based on current knowledge, an ‘irreversible’ decision would only be needed around 2050, with a new barrier possibly built in the 2070s, depending on the rise in sea level. Before then, a succession of short-term measures would be sufficient to maintain an adequate level of protection.

The Netherlands is heavily exposed to SLR, with 26 percent of its area below sea-level (a densely populated region responsible for 70 percent of its GDP) and an extra 29 percent susceptible to river flooding (Netherlands Environmental Assessment Agency, 2009). The “Make room for rivers” spatial planning project was the first to anticipate expected climate change impacts until 2100. The Delta commission then looked to develop an adaptation plan for the coastline, with clear recommendations pre-2050 (*e.g.* present flood protection levels of all diked areas to be raised by a factor of 10), a vision post-2050 and longer term considerations to 2200 (see Deltacommissie 2008).

Tipping points for infrastructure were identified, beyond which current management practices would be rendered unsuitable. Dessai and van de Sluijs (2007) showed how Dutch dykes may be designed flexibly. Initially the dykes are designed to deal with the most likely sea level. However, the foundations are strong enough to enable the construction of a future dyke on top if and when needed. This flexibility is not cost-free. Among other factors the design carries a heavier demand for land which otherwise could be used for alternative purposes.

Figure 5. TE 2100 builds in the flexibility to change protection strategy as new information about water levels becomes available.



Note: vertical dotted lines (red) – predicted maximums for water level rise in each scenario
Four packages of measures identified (colour coded)

Source: Reeder and Ranger (2010)

5. Who should adapt: Adaptation responsibilities

Explicitly or implicitly, much of the discourse on adaptation treats it as a public policy issue. This does not mean that adaptation is the sole or even primary responsibility of government. Most adaptation will be undertaken by households and the private sector. Yet there is an important role for public policy. There are well-established principles in public sector economics on the role of the state, and they apply to adaptation (Cimato and Mullen 2010). Accordingly, the state should involve itself in adaptation primarily for three reasons:

- ***Climate-resilient public goods***: Public goods like infrastructure are generally provided or at least commissioned by the state. There may be an increased demand for public goods specifically dedicated to adaptation, such as better sea defences. In addition, as the provider of traditional public goods like water supply networks, it may also fall to the state to ensure they are “climate proof”.
- ***Barriers to adaptation***: Market imperfections, policy failures and behavioural barriers may prevent or distort the uptake of adaptation measures. It is a classic function of the state to remove such barriers and create an environment that is conducive to effective adaptation.
- ***Assistance to vulnerable groups***: Another key role of government is to assist population groups that cannot adapt sufficiently themselves. Public bodies will have an important role to play in protecting vulnerable segments of the populations against climate change, including through emergency services.

European governments are beginning to grapple with these responsibilities as they are devising their national adaptation strategies (see Table 3). They explore ways to incorporate adaptation into sector policies, and there is the issue of reviewing, monitoring and enforcing adaptation policies. To date, only Finland, Germany and the UK have put in place formal review and monitoring procedures (Swart *et al*. 2009). At pan-EU level the European Commission's White Paper on Adaptation (European Commission 2009) exhorts member states to "*promote strategies which increase the resilience to climate change of health, property and the productive functions of land, inter alia by improving the management of water resource and ecosystems.*" The Commission seeks to develop a comprehensive adaptation strategy by 2013.

This section reviews the case for public adaptation and the approach European governments have taken to it.

5.1 Public goods

Some adaptation measures clearly have the character of public goods. That is, they will be non-rival and non-excludable. Typical examples include community-level flood protection, storm warning systems or coastal defence structures. Climate information – in the form of climate change model runs or impact scenarios, for example – can in principle be made excludable, but most analysts would agree that information has public good features. The same holds for research and development, for example in drought-resistant crops or new treatments against weather-related diseases. It is possible to protect the intellectual property of innovators in these areas, but innovation clearly has aspects of a public good.

Table 3 To date, twelve EU countries have adopted national adaptation to climate change strategies

	Date of plan	Type of approach	Focus	Challenges	Comments
Belgium	2010	bottom-up approach: local and sectoral	health, tourism, agriculture, forestry, coasts, biodiversity	spatial planning	stresses the importance of international cooperation
Denmark	2008	autonomous adaptation by vulnerable stakeholders	national level adaptation measures	developing modelling tools for adaptation; coordination and knowledge sharing	role of government limited to providing information
Finland	2005	comprehensive, science-policy interactions		multi-sectoral cooperation, knowledge gaps	strategy relatively general, encouraging sectoral policies to be developed
France	2006	limited adaptation focus	public security and health, equity, natural heritage	financing adaptation; clarity of responsibility	government appears to favour short-term measures, *i.e.* mitigation rather than adaptation
Germany	2008	comprehensive; science based		adopting new regulatory standards of environmental protection, water management	effective science policy interface; monitoring and revision announced
Hungary	2008	comprehensive	health, water management, agriculture/ forestry, rural development, environment	no enacting legislation, no targets or funding mechanisms	most of the funding is expected to come from the EU structural and Cohesion and Rural Development Fund
Nether lands	2008	scientific approach, cross-sectoral	water management, coastal protection, spatial planning	division of responsibilities	by limiting GHG emissions – less adaptation required
Norway	2008	comprehensive, local, sectoral			existing distribution of responsibilities among governmental, regional and local authorities to be maintained
Portugal	2010	sectoral approach	water, fires, tourism	multi-level governance	high public involvement
Spain	2006	comprehensive, integration with mitigation		raising stakeholder interest	coordination between national level and autonomous regions
Sweden	2009	cross-sectoral, local, regional and national			
United Kingdom	2008	comprehensive, scientific, local level			To be updated in 2013, based on a comprehensive risk assessment

Sources: Swart *et al*. (2009), Carina and Keskitalo (2010), www.eea.europa.eu/themes/climate/national-adaptation-strategies

Public goods are underprovided by the market and governments intervene to correct this failure. In some cases government agencies become the provider of the goods – for example, in the case of state-owned infrastructure utilities – in other cases the state commissions their provision from the private sector or overcomes the market failure through regulatory means, such as the granting of patents.

Public goods related to climate protection (and by extension climate change adaptation) are typically provided directly by the state. There are very few flood protection, coastal defence or climate information projects that are provided through public-private partnerships or PPPs (Agrawala and Fankhauser 2008). Rare exceptions are the Broadland scheme in East Anglia (UK), where flood risk management in a 22,000 hectare area of special interest has been outsourced to a private contractor (Environment Agency 2009), and the Border Meuse project, one of the biggest river flood defence projects in the Netherlands.[15]

There are several factors that make PPPs for adaptation difficult (Agrawala and Fankhauser 2008, World Bank 2010b). Governments are attracted to PPPs either because a private contractor can provide a superior level of service or because the cost of the scheme can be moved off the government's balance sheet. Neither possibility is likely in the case of adaptation. Once built, the operation of adaptation schemes is relatively straightforward, leaving little room for efficiency gains through private management. Moreover, the lack of an independent revenue stream means contractors have to be paid by the government, probably against a set of performance indicators. This means the liability will remain on the government's balance sheet. For these reasons it is likely that dedicated adaptation measures of a public good nature will be the responsibility of the public sector, a fact recognised in most European national adaptation strategies.

Arguably the bigger task for the state, however, will be to "climate-proof" conventional public goods like national infrastructure. In cases where their provision has remained in state hands adaptation will also be a government responsibility. However, there are many instances where infrastructure services are provided by private contractors, such as private water utilities, energy companies or road concessionaires.

In those cases, the onus of adaptation will fall on the private contractor. Many contracts feature performance targets that already expose operators to climate risk, such as quality targets for water utilities, availability payments for road concessionaires or reliability targets for rail franchises. These targets force operators to manage climate risks and avoid underperformance as a consequence of adverse weather events. It remains an open question, though, to what extent regulators will recognise the cost of these actions as legitimate expenditures that can be passed on to consumers. This can raise political economy questions and the risk that regulatory barriers may prevent effective adaptation.

5.2 Barriers to adaptation

Although advanced societies are generally good at dealing with climatic conditions, the process of adaptation is neither smooth nor automatic. Case studies of adaptation behaviour with respect to both current and future climate risks (for example in the aftermath of hurricane Katrina), reveal an abundance of institutional, policy and market failures (Hanemann 2008; Sobel and Leeson 2006).

It is the role of government to address barriers to effective adaptation, including inadequacies in the government's own performance. Unlike the provision of public goods, which requires physical investment, the government's response to adaptation barriers is primarily institutional and regulatory. The main issues that will need government intervention can be grouped into three broad categories (Cimato and Mullen 2010; Productivity Commission 2011).

First, adaptation may be held back by shortcomings in the ***institutional and regulatory*** environment. In the UK, ASC (2011) hints at regulatory barriers (*e.g.* in the design of abstraction licences, limited water metering) that might hold back efficient adaptation in the water sector. Many of these problems are already manifest in the response to current climate risks. Sobel and Leeson (2006) detail how a layered bureaucracy, an incentive structure that rewards over-cautiousness and the political manipulation of relief aid, among other factors, hampered the response to hurricane Katrina. Institutional and regulatory barriers can be

[15] See http://www.vanoord.com/gb-en/our_activities/project_selector/border_meuse/index.php

overcome, as evidenced by Finland, which updated its *National Land Use Guidelines* to include both adaptation and mitigation guidance.

Second, adaptation decisions may be affected by multiple ***market failures***, some generic, others particular to adaptation. There may be asymmetric information, for example, between the buyer and seller of a property about its risk profile. There may be issues of moral hazard for people with insurance cover or with at-risk communities holding out for government assistance. Path dependence may affect the choice between protection and relocation. It is likely that highly vulnerable, but unique locations like Venice will be protected at all cost.

A key market failure is externalities and more generally the lack of coordination, for example between upriver and downriver communities. In a world with multilevel governance the need for coordination may be international as well as national and local. Coordinated EU action may be needed, for example, in integrated sectors such as agriculture, water, biodiversity, fisheries and energy networks (European Commission 2009). Not all externalities are necessarily negative. Tomkins and Eakin (2011) highlight the potential for positive spillovers from private action. As an example, urban home owners opting for plant gardens instead of patio decking generate benefits for themselves and other residents in terms of flood risk reduction, better water drainage and a more extensive habitat for wildlife.[16]

The third category are ***behavioural and information barriers.*** Complex, long-term adaptation decisions are knows to be affected by cognitive barriers. Hanemann (2008) talks about “the lack of perception of a need for action, and the lack of perception of a benefit from the action”. Cimato and Mullen (2010) identify inertia, procrastination and implicitly high discount rates as potential behavioural problems. Swart *et al.* (2009) note the low number of responses in the public consultation to the Spanish national adaptation strategy, for example. Millner *et al.* (2010) question the ability of decision makers to process rationally the available information.

The first challenge, however, is to provide good quality climate information. This is seen as a priority in many national adaptation strategies, in the UK for example through the work of the UK Climate Change Impacts Programme.[17] The European Commission too is actively supporting climate change impact research in programmes such as CLIMATEWATER, CLIMSAVE, FUTURESOC and others.

While addressing these barriers may require state intervention, governments themselves may be afflicted by information problems. Sobel and Leeson (2006) identify information problems as an important barrier in providing emergency assistance after hurricane Katrina.

5.3 Assistance to vulnerable groups

Addressing questions of fairness and equity is the purview of public policy, and adaptation raises many distributional questions. The issue is complicated by the fact that climate change itself is an agent of redistribution (Hanemann 2008), as different regions, sectors and population groups will be affected differently. The fact that disadvantaged population groups such as poor households and the elderly are likely to be affected disproportionately may well test social cohesion. More generally, people look to the state for basic protection, social safety nets and assistance in case of emergencies. When all other mechanisms fail, the state is likely to serve as insurer of last resort and to finance the reconstruction effort. As the impacts of climate change become more noticeable, demand for these essential public services will rise.

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16 ASC(2011) views the same issue as a negative externality related to the concreting over of garden areas

17 See www.ukcip.org.uk

Nevertheless, it remains an open (and highly political) question to what extent the costs of adaptation – for example, for a flood protection scheme – ought to be borne by the beneficiaries of the measure and to what extent they should be socialised across a larger population group. Different societies will come to different conclusions. Denmark's national adaptation strategy, for example, emphasises "autonomous adaptation", which implies the transfer of adaptation costs to stakeholders and communities. In contrast, the French system envisages the use of public funds to indemnify people in areas that are vulnerable to flooding. Portugal also requires the government to keep a high level of involvement (Swart *et al.* 2009). Finland's insurance-based compensation mechanism for extreme weather events, introduced in 2010, aims to strike a balance, transferring the cost burden gradually from the government to the private sector. Another critical element is solidarity with vulnerable populations abroad. Low-income countries will be hit much harder by the impacts of climate change and their capacity to adapt will often be limited (Barr *et al.* 2010, World Bank 2010b). Developed countries have pledged substantial amounts of additional funding for climate change in developing countries, both for adaptation and mitigation. The pledge made under the Copenhagen Accord is for an additional finance of US$100 billion a year by 2020. Most observers in developing country would not see this offer as an act of solidarity, but as a reflection of the "common but differentiated responsibilities" of rich countries under the UN Framework Convention on Climate Change. For some it is a form of compensation.

Whatever the motivation, ensuring climate-resilient development in low-income countries, through both official development assistance and additional climate finance, will be an important responsibility of European governments and aid agencies. European governments have been highly supportive of these efforts. However, how this is best done is still open and raises important questions of governance, adaptation effectiveness and the link between adaptation and development. This is discussed for example in Barr *et al.* (2010), Bowen *et al.* (2012), Fankhauser and Burton (2011), Klein and Möhner (2009), World Bank (2010a, 2010b).

6. Conclusions

This paper analyses adaptation priorities and challenges in Europe. Adaptation will become a permanent feature of future decision making, and given its ubiquity it is important to go about adaptation in a strategic way.

A strategic approach to adaptation involves setting priorities, both spatially and inter-temporally. Not every sector and country is equally vulnerable and not all adaptation has to start now, even if ultimately everybody will have to adapt. There is a question of *where* and *when* to adapt.

The paper reviews the available evidence on Europe's exposure, sensitivity and adaptive capacity to climate change to identify where the spatial adaptation priorities might lie. Most studies point to the fact that Southern Europe (and the Mediterranean region in particular) would be most affected, whilst Northern Europe could gain in some areas, while being adversely affected in others. The north-south climate change impacts gradient is likely to increase economic disparities that are already apparent and straining European cohesion. Although we have not attempted to measure the capacity to adapt, it is a reasonable conjecture that it will be lower in the southern and eastern parts of Europe. Adaptive capacity is strongly correlated with income.

Europe should also be concerned about climate change outside its borders, and in particular adaptation in low-income countries. The vulnerability of these countries is considerably higher than that of even the most affected part of Europe. International adaptation assistance is both an ethical imperative and an obligation rich countries have under the UN Framework Convention on Climate Change. It is also in Europe's self-interest, given how quickly climate effects can spread in an interconnected world.

In terms of inter-temporal priorities, adaptation theory recommends fast-tracking two types of action. The first are win-win measures that yield an immediate return. The second are strategic decisions that have long-term consequences and lock in an undesirable vulnerability profile. The paper provides examples of both types. Win-win adaptations include measures such as water efficiency (including appropriate pricing), improved flood protection, better emergency services and the careful management of the natural environment. Strategic decisions that should take climate change into account now include long-lived infrastructure investments, such as ports, roads and water supply networks, which will be in use long enough to experience a change in climate. Other examples of strategic decisions include the design of buildings and planning – *e.g.* the development of areas prone to floods, water shortages or wildfires.

A strategic approach to adaptation also involves careful project design: the question of *how* to adapt. It is easy to mis-specify adaptation measures. A key complication particularly for long-lived, strategic adaptations is that we do not know enough about the future climate to which long-lived assets need to be adapted. This deep level of uncertainty puts a premium on flexible designs that can be adjusted as new information becomes available. This makes behavioural or institutional adaptations particularly attractive. For example, in the water sector demand-side management may be more attractive than new investment in supply infrastructure. However, experience in the Netherlands and the UK shows that flexibility can also be introduced into large physical investments like flood defence schemes.

The final element of a strategic approach to adaptation is the allocation of responsibilities between the public and private sector: The question of *who* should adapt. The traditional functions of the state identified in economic theory also apply to adaptation policy. Adaptation is to a large extent a private activity. Yet, there is an important role for the state. The paper identifies three core government responsibilities. The first is the supply of public goods, which includes both the provision of public adaptation goods like flood defences and climate information, and the climate-proofing of conventional public goods, such as road and water networks. The second function of the state is to protect vulnerable population groups, for example by providing adaptation assistance or emergency services after extreme events. The third function is to remove market and policy barriers that may prevent effective adaptation. There are quite a few such barriers, including coordination problems between adapting communities, skill gaps and information asymmetries.

European countries are awakening to the challenge of adaptation. Quite a few of them have commissioned climate change impact / adaptation studies or have put in place a national adaptation strategy. Organisations that are used to dealing with climate variations, such as water companies and environment agencies, are beginning to factor climate change into their current approaches to climate risk. However, there are still many instances where business and policy decisions lead to an increase in vulnerability. Adaptation to climate change is not yet a mainstream policy issue.

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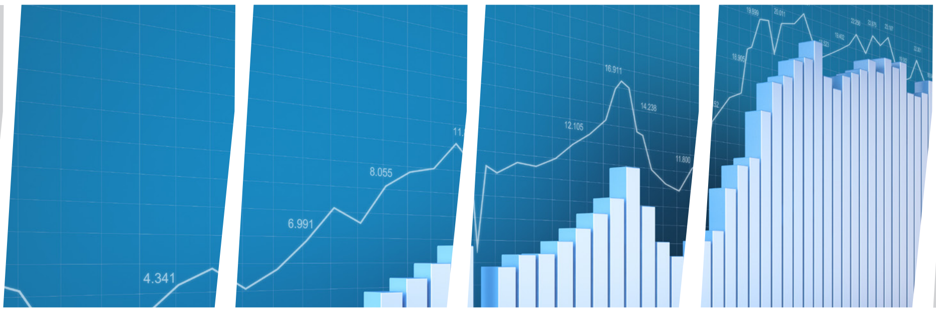

Contacts

For general information:

Information Desk
Corporate Responsibility and
Communication Department
(+352) 43 79 - 22000
(+352) 43 79 - 62000
info@eib.org

European Investment Bank
98-100, boulevard Konrad Adenauer
L-2950 Luxembourg
(+352) 43 79 - 1
(+352) 43 77 04
www.eib.org/economics