ACCLIMATISE
building climate resilience

COWI

Guidelines for Project Managers: Making vulnerable investments climate resilient

Report for the European Commission

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CLIMATE ACTION

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Contents

Glossary

Users should familiarise themselves with the key and concepts relating to climate change adaptation outlined below. These form the foundation of the structure of the Guidelines.

Term/concept	Definition
Adaptation options / measures	Actions reducing vulnerability to climate change and climate variability by preventing negative effects or by enhancing resilience to climate change. (ClimWatAdapt, 2012) In these Guidelines, the terms 'adaptation options / measures' and 'resilience measures' are used interchangeably
Adaptive capacity	The ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences that cannot be avoided or reduced.
Climate adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC, 2007a) The process, or outcome of a process, that leads to reduction in harm or risk of harm, or realisation of benefits, associated with climate variability and change. (Willows and Connell, 2003).
Climate Resilience Manager (CR Manager)	The person appointed by the Project Manager to oversee the climate resilience process set out in these Guidelines. This will likely be an existing member of the project team.
Donor	An entity which provides money to projects, generally in the form of grant financing, for the purposes of achieving societal benefits. In some instances, donors can help cover some essential costs of projects which may otherwise be unaffordable. In reality, the distinction between donors and *financiers* (see below) is not clear cut, e.g. some organisations provide funding which blends loans and grants.
Exposure	The nature and degree to which a system is exposed to significant climatic variations. Exposure is determined by the type, magnitude, timing and speed of climate events and variation to which a system is exposed (e.g. changing onset of the rainy season or minimum winter temperatures, floods, storms, heat waves). (World Bank, 2009).
Financier / investor	An organisation or individual who invests money in projects for financial return, usually involving private equity, venture capital or corporate finance. Some financiers will be driven by financial returns alone, and some by a mix of financial returns and socio-economic objectives, based on their specific mandates.
Grant	Transfers made in cash, goods or services for which no repayment is required. (OECD).
Hazard	A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. (UN/ISDR, 2004).
Maladaptation / maladaptive action	Action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other

	systems, sectors or social groups. (Barnett and O'Neill, 2010).
Mitigation	An intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. (IPCC, 2007a).
Probability	The chance or relative frequency of occurrence of particular types of events, or sequences or combinations of such events. (Willows and Connell, 2003).
Project developer	The organisation(s) managing development and operations of a project. In project finance, also referred to as the 'project promoter'.
Project manager (PM)	The person in overall charge of managing a project lifecycle, with responsibilities that can include planning, execution and closing of a project.
Repayable finance	Financial flows that require repayment at a future date plus remuneration for the use of capital, in the form of interest or dividends. This may include loans, bonds and equity. Market-based repayable finance and concessionary repayable finance are sub-sets of repayable finance. (OECD, 2010)
Resilience	The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. (UN/ISDR, 2004)
Resilience measures	Actions reducing vulnerability to climate change and climate variability by enhancing resilience. In these Guidelines, the terms 'resilience measures' and 'adaptation options / measures are used interchangeably
Risk	Risk is a combination of the chance or probability of an event occurring, and the impact or consequences associated with that event. (Willows and Connell, 2003).
Risk assessment	A methodology to determine the nature and extent of risk by analysing potential hazards, evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend, assessing the likelihoods and severities of impacts, and assessing the significance of the risk [...]. (UN/ISDR, 2004 and Willows and Connell, 2003).
Robust adaptation	Measures that allow a system to perform satisfactorily and remain resilient under both current and future climate conditions. (Adapted from Willows and Connell, 2003).
Sensitivity	The degree to which a system 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). (IPCC, 2007a).
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. (UN/ISDR, 2004).
Vulnerability assessment	Identifies who and what is exposed and sensitive to change. (Adapted from Tompkins et al., 2005 in Levina and Tirpak, 2006).

1 Part 1: Introduction to the Guidelines

1.1 Aims and objectives of these Guidelines

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.

These Guidelines form part of the overall EU effort to mainstream climate change adaptation, following on from the White Paper on Adapting to Climate Change[1] published by the Commission in 2009. They are designed to provide support to developers of physical assets and infrastructure.

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 are intended:

- to help manage the additional risks from climate change,
- to complement and integrate within the familiar project appraisal processes used in project development, but
- not to replace existing project development processes.

They explain when and how to apply seven modules which make up the climate resilience toolkit. The modules will help to:

- consider how a project is vulnerable to climate variability and change,
- assess current and future climate risks to the success of the project,
- identify and appraise relevant and cost-effective adaptation options to build climate resilience, and
- integrate adaptation measures (resilience measures) into the project lifecycle.

Application of these Guidelines should help to minimise climate change related loss to public, private and combined public/private investments, leading to more robust investment projects and, ultimately, more resilient economies. They should help developers to improve the success of investment projects and ensure their long-term sustainability.

By using these Guidelines, project developers can also demonstrate to project funders/financiers that climate resilience has been considered.

Finally, it is worth mentioning that experience on adaptation is still evolving. These Guidelines should be seen as an active, dynamic toolkit, which may be updated in the future based on lessons learned from their application in real-life projects.

[1] See COM(2009) 147 final, Section 3.2.5

1.2 Applicability of these Guidelines

The Guidelines can be applied for two types of project:

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

Annex I presents a typology of investment / project types for which the Guidelines have been designed[2].

To help developers identify *climate-influenced* projects and decide whether to apply the Guidelines, the checklist below can be used. If the answer to one or more of the checklist questions is 'yes', the project may be affected by climate change. In these cases, it is recommended that the high level assessments described in Modules 1 to 3 of the Guidelines are undertaken, before deciding whether to apply any other modules (see Part 2 for further details).

The Guidelines can be applied to all *climate adaptation* projects.

	Checklist to identify climate-influenced projects	If 'yes' insert '✓'
1	Is the lifetime of the project 20 years or more? *It is on these timescales that climate change impacts will increasingly be felt.*	☐
2	Are the project options in climatically-exposed locations (see Table 1 below)?	☐
3	Is water an integral part of operations, products or services? *'Integral part' refers to the use of water as a major component of an operation (e.g. cooling water for a production process), a product (e.g. beverage manufacturing) or a service (e.g. industrial cleaning).*	☐
4	Are the energy supplies for the project options vulnerable to disruption?	☐
5	Do some of the operations or products depend on other supplies or services whose availability or price is sensitive to climate conditions or weather events?	☐
6	Are transport routes for the project options vulnerable to weather disruption (e.g. by storms, floods, landslides etc)?	☐
7	Are the project's facilities or operations negatively affected by higher temperatures? Can this lead to reduced productivity, higher costs or equipment failure?	☐
8	Will the project's workforce be exposed to temperature stress or weather events e.g. in non-air conditioned or poorly ventilated buildings, or working outside?	☐
9	Is demand for the project's products or services sensitive to weather or climate conditions?	☐

[2] Types of projects broadly fall within one of the following categories: infrastructure, energy, construction (buildings) and industry.

The Commission strongly encourages the use of the Guidelines, both in EU-funded projects and more widely. They sit within the evolving policy context on adaptation in the Commission, which is seeing climate resilience being incorporated into a number of policy areas and financing instruments of relevance to asset and infrastructure (some examples are provided in Section 1.4).

EU and national institutions as well as financial organisations could consider whether they want to recommend or require use of the guidelines for projects they finance.

Individual Member States will have varying legislative and regulatory standards governing project design. Furthermore, some Member States are beginning to incorporate requirements for climate risk assessment and/or climate change resilience into legislation. Similarly, some professional institutions have revised their design guidance to incorporate future climate change[3].

These Guidelines are not intended to override, nor define, the design standards that project developers should be working to, and they are not a substitute for detailed design at the project level. Project design should always be undertaken in accordance with national requirements and/or professional codes of practice as appropriate. However, in cases where national requirements or design codes do not yet incorporate consideration of climate change, these Guidelines may help to improve risk management still further.

Table 1: Geographic locations exposed to increased climatic variability and climate change

Changing climate hazard	**Particularly exposed locations**
Average temperature rise and increased risk of heat waves	• Regions where average temperatures are already high, • Regions where temperature thresholds may be crossed (e.g. permafrost zones, mountainous regions), • Urban centres, where the Urban Heat Island effect (the localised pool of warm air that frequently builds up over towns and cities) will exacerbate high temperatures, • Regions with limited freshwater supplies.
Mean sea level rise, increased storms surge heights, wave heights, coastal flooding and erosion	• Areas already at or below sea level, • Coastal zones and islands, • Offshore locations.
Decreased seasonal precipitation, increased risks of drought, subsidence and wildfire	• Regions where rainfall is already scarce, • Locations where current demand for water almost matches or outstrips supply, • Locations where water quality is poor, • Water resources dependent on glaciers, • Subsidence-prone soils, • Regions prone to wildfire, • Trans-boundary river basins where tensions already exist over water use.

[3] For instance, the UK Chartered Institute of Building Services Engineers, CIBSE, see http://www.cibse.org/index.cfm?go=page.view&item=1300

Increased seasonal precipitation and more rapid snow melt, leading to increased risk of river flooding. Increases in heavy precipitation events leading to increased risk of flash floods and soil erosion	• Regions with high rainfall, • Estuaries, deltas and river floodplains, • Mountainous and glacial regions, • Locations prone to landslip, • Urban centres with stormwater systems that are not designed to manage short duration intense rainstorms, • Contaminated environments (land, water).
Possible increased storm intensity and frequency	• Areas at risk from tropical storms (including hurricanes, typhoons, cyclones) and extra-tropical storm events particularly in urban areas.

Disaster risk reduction

The World Bank estimates that for every dollar invested in pre-disaster risk reduction activities (in developing countries) seven dollars in losses can be averted (UNDP (2007).

Although the focus of these Guidelines is on climate-related risks and their management, in general, many of the tools and approaches described can also be used by project developers to understand and manage other types of risks (for example, geophysical, industrial and technological risks[4]). (See Section 1.4 box on EU Member State Risk Assessment and Guidelines for Disaster Management.)

1.3 Proportionality in applying the Guidelines

The Guidelines have been written so as to minimise additional workload and costs for project developers. As already noted, the modules have been designed to integrate into the routine analyses undertaken as part of project development (such as pre-feasibility studies, site selection decisions, environmental (and social) impact assessments, etc, see Section 2.1). Hence, the outputs from applying the modules will be modified versions of these routine analyses, with climate change issues built in. It is estimated that application of the modules could typically add 1% to 10% to the costs of these routine analyses.

Furthermore, it will always not be necessary for project developers to work through all of the modules, and so there are various 'exit points' described in Part 2 – for instance, after the pre-feasibility study.

[4] Project developers will also need to assess and manage other natural and man-made risks relevant to their project e.g. geophysical risks, risk of accidents (including industrial / technological risks) and their potential interactions with climate hazards.

1.4 Other relevant EU policy instruments and guidelines relevant to assets and infrastructure

Provisions on mainstreaming and tracking climate related expenditure in the next Multiannual Financial Framework 2014-2020, 'A Budget for Europe 2020'

Climate action on mitigation and adaptation is already integrated into many EU policy areas and implemented through a range of instruments, and a proportion of the current EU budget is related to climate mainstreaming. The Commission intends to increase the proportion to at least 20%, with contributions from different policies. To achieve this, the climate-related share of the EU budget for 2014-2020[5] must be significantly increased, including through investments in projects that are not exclusively climate-related, but which have a significant climate component. Also, tracking of climate-related expenditure will be integrated into the existing methodology for measuring performance used for EU programmes.

The EC has adopted a draft legislative package to modernise the operation of a number of funds covered by the Common Strategic Framework and align them with the sustainable growth objectives outlined in the Europe 2020 Strategy[6]. The package is currently under negotiation with Member States and the European Parliament and may be subject to change. Key elements relevant to climate change adaptation of infrastructure are outlined below.

"Regulation laying down common provisions for the Common Strategic Framework"
This proposed regulation [7] lays down common and general provisions for a number of funds covered by the Common Strategic Framework, including (of relevance to infrastructure) the European Regional Development Fund and the Cohesion Fund.

Key actions for the European Regional Development Fund and Cohesion Fund include supporting investment aimed at increasing adaptation to climate change. This includes avoiding damage to built environment and other infrastructure, decreasing future pressure on water resources and investing in flood and coastal defences.

"Connecting Europe Facility"
In its proposal 'A Budget for Europe 2020', the Commission decided to propose the creation of a new integrated instrument for investing in EU infrastructure priorities in Transport, Energy and Telecommunications, the 'Connecting Europe Facility' (CEF). A proposed regulation sets out the provisions governing the CEF[8], and at the same time, revised Guidelines are proposed for Transport, Energy and Telecommunications. The

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[5] On 29 June 2011, the European Commission presented its proposal for the multi-annual budget for 2014-2020, 'A Budget for Europe 2020', which focuses on priority funding at the EU level. Legislative proposals for each area covered by the budget will be published by the European Commission and the proposals will be discussed by the Council and European Parliament during 2012-2013. It will start in 2014. (See http://ec.europa.eu/budget/reform/commission-proposals-for-the-multiannual-financial-framework-2014-2020/index_en.htm

[6] See http://ec.europa.eu/europe2020/index_en.htm

[7] COM(2011) 615 final/2, see http://ec.europa.eu/regional_policy/sources/docoffic/official/regulation/pdf/2014/proposals/regulation/general/general_proposal_en.pdf

[8] COM(2011) 665/3, see http://ec.europa.eu/transport/infrastruc-ture/connecting/doc/connect-ing/proposition.pdf

overall aims of the proposed regulation are to:

- promote smart, sustainable and fully interconnected transport, energy and digital networks,
- boost Europe's competitiveness through key infrastructure investments, and
- allow the EU to meet its sustainable growth objectives outlined in the Europe 2020 Strategy and the EU's "20-20-20" objectives in the area of energy and climate policy.

The proposed regulation covers incorporation of climate adaptation / resilience in the preparation, design and implementation of infrastructure investments.

EC Guide to Cost Benefit Analysis of Investment Projects

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[9].

The CBA methodology presented in these Guidelines (Module 6) is not a substitute for these requirements. Module 6 aims to provide a structured process for integrating climate change risks and uncertainty into adaption options appraisal, with a view to selecting the options that maximise the net benefits in terms of increased resilience to current and future climate.

EC Guidance for integrating climate change and biodiversity into Environmental Impact Assessments (EIAs)

At the time of writing these Guidelines, the EC's DG Environment, Cohesion Policy and Environmental Impact Assessment Unit 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. The Guidance is applicable across all EU Member States. The Guidance recommends that climate change is built into assessment processes at the earliest stages, and that climate change issues must be tailored to the specific context of a project.

These Guidelines can be used in combination with the EIA Guidance, which provides more detailed information on addressing climate risks in the EIA stages of a project.

EU Member State Risk Assessment and Guidelines for Disaster Management

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

[9] See http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

transparency and co-operation 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.

The main underlying principles and recommendations in the Disaster Management Guidelines could well be replicated at lower local and regional levels and applied by other relevant stakeholders such as project developers. The Disaster Management Guidelines can be used in conjunction with these Climate Resilience Guidelines to extend out to other types of risk (for example, geophysical).

It is also recommended that, where available, national risk assessments and accompanying risks maps are reviewed as an additional source of information when using these Climate Resilience Guidelines.

The initiatives undertaken within the EU prevention and risk management policy are closely linked to climate change adaptation and provide scope for synergies, including within the priorities for prevention work in the short term which are:

- A best practice programme leading to EU guidelines on minimum standards for disaster prevention (2013) focusing on governance, planning, research and disaster data
- An overview of the major risks the EU may face in the future (2012) based on the national risk analysis derived from the Member States' risk assessment.

Further information is available on the DG ECHO website[10].

1.5 The role of public financial institutions, commercial banks and insurers

"As they channel investment, financial institutions have an opportunity and responsibility to take a leading role in...adapting to climate change. Institutions managing investments in long-term assets should consider the financial risks associated with climate change, as well as the opportunity to create value by working proactively with clients and stakeholders to manage the risks."

Rachel Kyte
IFC Vice President, Business Advisory Services

In Europe, the European Financing Institutions Working Group on Adaptation to Climate Change (EUFI WACC) whose members include the European Commission, European Investment Bank (EIB), EBRD, l'Agence française de développement (AFD), KfW, Nordic Investment Bank (NIB) and the Council of Europe Development Bank (CEB) aims to support the EU agenda and objectives for financing adaptation to climate change. Financial institutions in EUFIWACC are already mainstreaming climate change risk management into their due diligence investment appraisal and monitoring processes. Other financial institutions worldwide, such as the International Finance Corporation (IFC), Asian Development Bank (ADB) and African Development Bank (AfDB) are also undertaking pioneering work to mainstream climate resilience and adaptation.

[10] See http://ec.europa.eu/echo/policies/prevention_preparedness/prevention_en.htm

How financial institutions are addressing climate risk and adaptation[11]

l'Agence française de développement (AFD) has adopted a case-by-case approach on adaptation projects, assessing climate risks and resilience using multiple metrics. Criteria and specifications are used to determine whether a project will reduce proven risks or increase the resilience of a community. The criteria used include existing vulnerability based on geography and the type of action that can help reduce vulnerability or increase resilience among the populations.

The **Asian Development Bank (ADB)** are preparing and testing technical guidance and tools to help both assess the vulnerability of projects to climate change and to climate-proof vulnerable investments. These include the 'Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects'[12] which provides a step-by-step approach to help project teams to incorporate adaptation in transport projects. In advance of producing the Guidelines, the ADB also completed high level studies on project level climate proofing. These covered the economics of adaptation using two road development projects as case studies[13] and identifying climate risks and adaptation options for the power sector[14].

European Bank for Reconstruction and Development (EBRD) undertook a project to develop a methodology for understanding the risks posed by climate change and impacts on the bank's operations. This is helping climate resilience to be included in investment projects where appropriate. The project developed guidance and practical tools to integrate climate risk assessment and adaptation into EBRD's project cycle. EBRD is also participating in the Pilot Programme for Climate Resilience (PPCR), implemented under the Climate Investment Fund. PPCR is pioneering pro-adaptation technical assistance and investment projects.

European Investment Bank (EIB) have recently developed a number of sector strategies which include addressing climate change adaptation. The EIB will only finance projects that fulfil the requirements described in their Environmental and Social Statement and Handbook. This includes projects applying cost effective, appropriate adaptation measures where there is a risk of significant adverse impacts from climate change and increased frequency of extreme weather events. The EIB also actively promote adaptation projects such as water resource management.

KfW Entwicklungsbank's projects undergo a systematic two step climate change assessment to ensure potential impacts are managed and opportunities are capitalised. The first step is an initial assessment to assess risks of anticipated climate change and opportunities for additional mitigation measures. If significant climate change risks or mitigation potentials are identified, a more detailed second stage is undertaken. A modification of the project design, the implementation of risk

[11] Summary results of a review of eight financial institutions and their screening criteria and appraisal tools for climate related finance. The study for DG CLIMA, "Cooperation with EU financial institutions: climate related standards in assessing investments and infrastructure projects" is in progress at the time of writing these Guidelines, and is being undertaken by the consortium AEAT, ODI and Adelphi.
[12] http://www.adb.org/documents/guidelines-climate-proofing-investment-transport-sector-road-infrastructure-projects
[13] http://www.adb.org/publications/economics-climate-proofing-project-level-two-pacific-case-studies
[14] http://www.adb.org/publications/climate-risk-and-adaptation-electric-power-sector

mitigation measures or an additional project phase could result from this in-depth analysis.

Inter-American bank (IDB) under its 3rd 'strategic line for intervention'[15] states that it 'will ensure that investments in infrastructure (such as transport, water and energy) and other areas that may be sensitive to the impacts of climate change are designed to withstand those impacts. To this end, it will develop the capacity to assess the vulnerability of the projects it finances to climate variability and change...'

International Finance Corporation (IFC) created a Climate Risk Working Group to identify risks of climate change at the investment and post-investment stage. Their Performance Standards state the importance of identifying risks and impacts of climate change. The IFC is currently supporting three Pilot Program for Climate Resilience (PPCR) projects. In 2008, IFC initiated the Climate Risk Program[16], a series of pilot studies analysing climate risks and adaptation options for a range of projects in different sectors and regions. The objective was to test and develop methods for evaluating climate risks to the private sector and to identify appropriate adaptation responses.

At the **World Bank (WB)**, in response to the most recent replenishment of the International Development Association's[17] resources (IDA-16) work is underway to develop tools for more systematic treatment of climate impacts. These will also be relevant for International Bank for Reconstruction and Development (IBRD) countries. Key products include a methodology for mainstreaming climate impacts at the strategic level and sector guidance for select climate sensitive sectors (agriculture, water, roads) at the project level. Tools that are already available include:

- Rapid Assessment of Climate Change Vulnerability, Risk and Adaptation in the Energy Sector,
- Urban Risk Assessment (URA) tool for assessing disaster and climate risk in cities[18],
- Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects[19].

Some commercial banks are also reviewing their due diligence processes for climate risks and have been engaged in adaptation research over a number of years. Notable among these are Barclays, HSBC and Standard Chartered.

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[15] IDB integrated strategy for climate change and mitigation, and for Sustainable and Renewable Energy. The ambition is that the IDB will 'strengthen and consolidate its own capacity, readiness, comparative advantages, and will equip itself to become a catalyst for ...responding effectively to the growing demand for climate change mitigation action and climate resilience.'

[16] http://www1.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/CB_Home/Policies+and+Tools/Assessing+Climate+Risks/

[17] The International Development Association (IDA) is the part of the World Bank that helps the world's poorest countries. IDA aims to reduce poverty by providing loans and grants for programs that boost economic growth, reduce inequalities, and improve people's living conditions. See http://www.worldbank.org/ida/what-is-ida.html.

[18] http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1312495777257/UrbanRiskAssessmentWeb.pdf

[19] http://climatechange.worldbank.org/content/how-use-guidance-notes

Insurers have, for some time, observed trends of increasing insured losses due to weather-related events. As a result, they have been among the most active in pressing for progress on adaptation. Many insurers state that they have begun to institutionalise climate change risk management into underwriting, investment, and asset management. Some now also state that adaptation can lead to more favourable insurance terms for insured assets.

The above activities show that project developers are increasingly likely to be required to demonstrate that climate change risks and vulnerabilities have been assessed, and appropriate climate resilience measures have been integrated into projects, before grants, loans and investments are approved.

1.6 Background to climate change

Climate change is underway and cannot be stopped completely. Action to mitigate greenhouse gas emissions is essential to avoid the worst effects over the longer-term. However, some changes are already built into the climate system, with inevitable consequences. Unless the vulnerabilities and risks are managed appropriately, climate change will increasingly affect project performance and the investments made in these projects.

There will be changes in average climate conditions and more frequent, more intense extreme climatic events. Extreme events will also occur in new locations that were not previously considered vulnerable. There may also be abrupt, irreversible changes when the climate system crosses so-called 'tipping points', triggering a transition to a new state[20]. As a result, the past may not be a good guide to the future, and decisions based on historic climate data may no longer be robust.

Even small climatic changes can have significant implications. The hot summer of 2003 across Europe was a 1 in 500 year event. It led to more than 35,000 deaths and economic impacts in many countries. By 2040, due to rising temperatures, this is expected to be a 1 in 2 year event.

Hottest months strain power supplies

During the hot summer of 2003, 17 nuclear reactors in France operated at reduced capacity or were forced to shut down, because river cooling water had reached maximum allowable temperatures. As a result, EDF (the French state-owned electricity provider) was forced to purchase electricity on the open market at 10 times usual summer rates. EDF severely restricted power exports, increased imports from subsidiaries abroad and negotiated reduced electricity consumption provisions with major industrial clients. This led to major electricity price spikes due to shortages in supply (up to 1300%), which EDF could not pass onto customers. Losses to EDF were reported to be €300 million.

Projected changes in temperature and precipitation across the EU region in the coming decades are shown in Figure 1 and Figure 2. The key points can be summarised as follows:

[20] For instance, summer Arctic sea-ice loss, melting of the Greenland ice sheet, shut-off of the Atlantic Thermohaline Circulation (THC), and die-back of the Amazon rainforest.

- Wintertime temperature increases are expected to be greater in north-east Europe (+2.5-3.0°C by the 2050s) than in the south-west.
- Summertime temperatures may increase in south Europe by up to 2.5°C by the 2050s. Given that these countries already experience some of the hottest summer temperatures in the region, these increases are expected to have detrimental impacts on many most industry sectors, the environment and society.
- Average winter precipitation is projected to increase over much of Europe. Some countries in northern Europe may see in excess of 25% increase by the 2050s. However, some in southern Europe are more likely to experience decreases, with consequential impacts on water users.
- Average summer precipitation is projected to decrease generally over much of southern Europe, with some countries projected to see decreases of up to 50% by the 2050s. Coupled with higher summer temperatures this could lead to increased water stress, impacting particularly on high water use sectors.

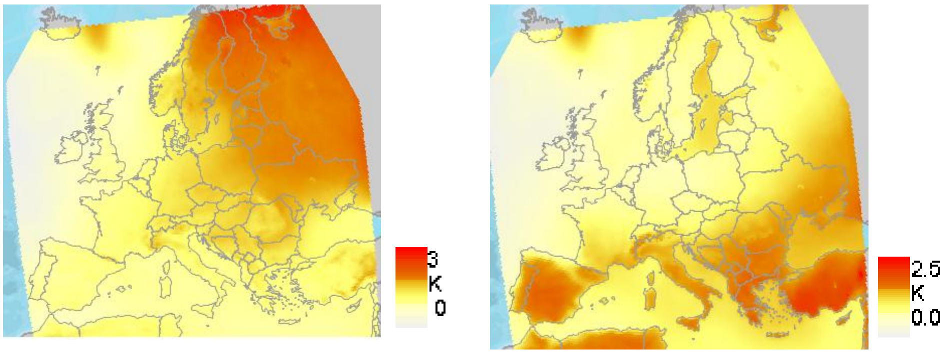


Figure 1: Average change in winter (left) and summer (right) temperature (°C or K) by 2021-2050 relative to 1961-1990 (A1B emissions scenario). [European Climate Adaptation Platform[21]]

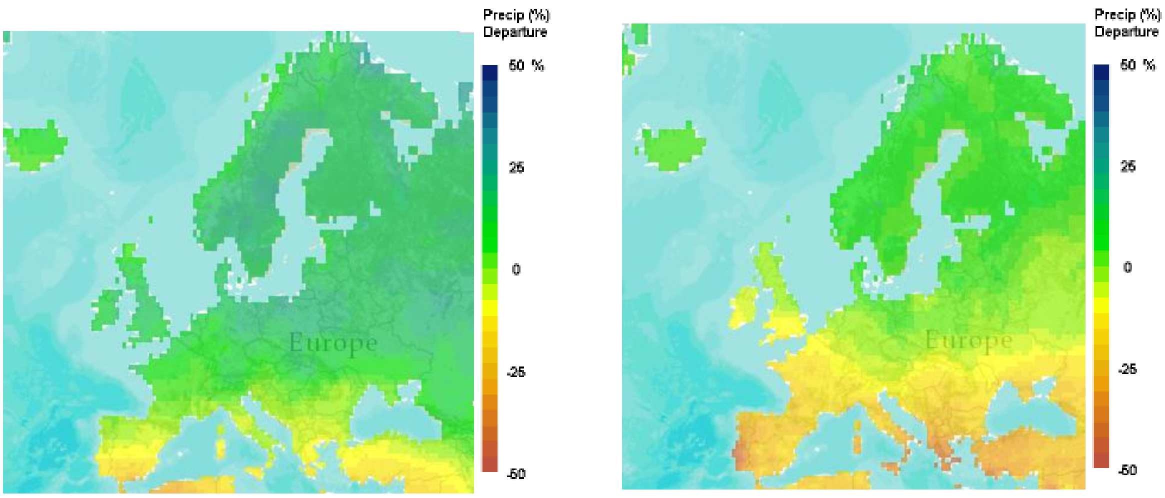


Figure 2: Annual mean change in winter (left) and summer (right) precipitation (%), 2050s relative to 1961 - 1990, (ensemble average, A1B emissions scenario) [Climate Wizard[22]].

[21] http://climate-adapt.eea.europa.eu/map-viewer
[22] The Nature Conservancy: Climate Wizard data portal (http://www.climatewizard.org/)

1.7 Consequences of climate change for physical assets and infrastructure

Design thresholds which are built into project designs may be breached more frequently in a future changing climate. A changing climate may result in threshold failures once considered exceptional but acceptable, becoming unexceptional (i.e. normal) and unacceptable. Projects may have to function within tighter margins between “normal” operation and critical thresholds. This may manifest itself in decreased efficiency of equipment and provide less margin for error before drastic management measures such as reduced operation, throughput etc need to be actioned.

Climate change will also affect the environmental and social systems around physical assets and their interactions with these systems. For instance, reductions in rainfall may affect the availability and quality of water resources on which industrial assets depend. At the same time, farmers may find they need to irrigate crops for the first time in response to rising temperatures and lower rainfall. Such changes may create competition and could potentially lead to conflict. This highlights the importance of thinking in an integrated, cross-sectoral way about climate risk and resilience[23].

Left unmanaged, climate change:

- will increasingly affect the operational, financial, environmental and social performance of large fixed assets and infrastructure,
- will interact with many of the risk factors relevant to projects.

For instance, availability of water resources may be reduced, operating efficiencies of equipment may be reduced due to higher temperatures, and rising sea levels may increase flood risk and erosion for coastal assets. As the impacts of climate change intensify, there will be macro-economic consequences in some areas, potential demographic shifts and changing patterns of land use. These, in turn, may affect demand for assets and infrastructure in these areas.

Ultimately, through its impacts on operational, environmental and social performance, and market conditions, climate change could result in:

- asset deterioration and reduced life,
- increases in OPEX and the need for additional CAPEX,
- loss of income,
- increased risks of environmental damage and litigation,
- reputation damage,
- changes in market demand for goods and services, and
- increased insurance costs or lack of insurance availability.

[23] Approaches such as Integrated Water Resources Management (IWRM, a process which promotes the coordinated development and management of water, land and related resources) can help to facilitate this integrated thinking. See, for instance, http://www.gwp.org/The-Challenge/What-is-IWRM/ and http://www.un.org/waterforlifedecade/iwrm.shtml.

1.7.1 Adapting asset and infrastructure systems and their components

Some adaptation actions will already be familiar to project developers

Adapting to climate change is not a wholly new concept. Societies, economies and infrastructure have adapted to climate variability and historic extremes long before the issue of man-made climate change arose. The difference now is that designs need to take into account not only today's climate but also potential changes in future climate, to ensure that projects continue to perform satisfactorily over their lifetimes. This is especially important for projects with long life spans (more than 20 years or so).

Often, the technologies used in the recent past will continue to work, as long as additional headroom / safety factors for climate change are applied. Technologies or approaches may be transferred from countries whose climate is similar now to the one faced by other countries in the future, e.g. road surfaces that withstand higher extremes of temperature. In other cases, new technologies will be required.

When embarking on adaptation of asset and infrastructure, there are a number of issues related to the whole system and its individual components which need to be considered:

- Some projects will require a systems approach[24] to adaptation planning and design. This can deliver significant cost savings through compatibility, consistency, redundancy and resilience. For example the railway is a 'system of systems'. By designing the *interfaces* between these various systems cost savings are achieved, and so the interfaces need to be considered when making decisions about how to adapt. In the case of rail, for instance, track is designed to interact with the earthwork it sits upon, the rail is designed to match the vehicle wheel, the earthwork is designed to support the track and electrification masts, the wheel and its suspension are designed to match the rail characteristics, etc.

- In some types of infrastructure project (e.g. transport), new build projects will often have to interface with existing assets. When selecting adaptation measures for the new build project, it is important to consider how the measures might affect the whole system and its vulnerability.

- Individual components of an asset or infrastructure project may have different lifetimes, with some elements expected to be renewed on a fairly frequent basis (e.g. every 5 – 10 years for some road surfaces) and others having lives of many decades (e.g. bridges). Decisions about adaptation will need to take account of these differences. Components with short lifespan do not need to take account of climate change, but it is important for longer-lived ones.

[24] 'Systems thinking' is the process of understanding how parts of a system influence one another within a whole. It is based on the view that the components of a system can be best understood by looking at their relationships with each other and with other systems, rather than in isolation.

1.8 Making robust decisions in the face of uncertainty

The key aims when undertaking climate vulnerability and risk assessments are to determine the sensitivity of project options to relevant climate-related hazards, identify exposure of the options to current and future hazards in a particular location(s), and identify and prioritise key risks. This information helps to determine options which are robust to current climate variability and also the range of future change.

The primary purpose of climate change vulnerability and risk assessments is to inform adaptation planning. Traditionally, this has been achieved through so-called 'top down' or 'scenario-led' methods which focus on developing fine scale climate data from coarse scale Global Climate Models (GCMs). The resulting local-scale scenarios are fed into impact models or mapped against the locations of project options (or existing assets) to determine vulnerability.

Although climate models are constantly being improved, they are not good enough to predict future climate conditions with a degree of confidence which would allow precise adaptation decisions to be made. Outputs from different climate models often differ, presenting users with a range of possible climate futures to consider, and ultimately a wide range of possible adaptation options (see Figure 3). Even with improvements in climate modelling, uncertainties will remain.

Downscaling climate projections to a higher resolution:

- should not be seen as increasing confidence in data, and
- can be wrongly interpreted as providing more accurate data.

The need for high-resolution climate data for long-term planning can be questioned in cases where climate variability is already stressing human and environmental systems[25]. In these cases, managing existing stresses is clearly a priority, while also maintaining the flexibility to cope with the range of potential impacts of future climate change.

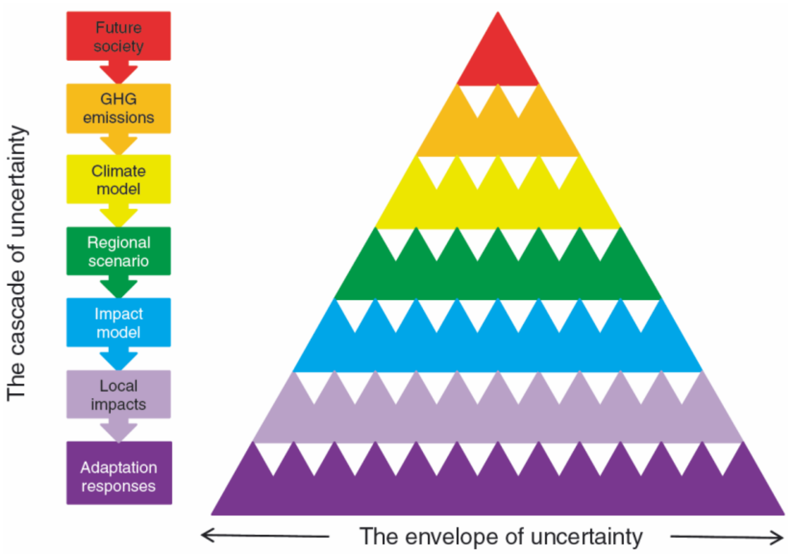
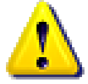


Figure 3: The cascade of uncertainty. [Source: Wilby and Dessai, 2010]

[25] See Wilby and Dessai (2010)

Related, it is likely that not all the climate statistics of relevance to the design, planning and operations of assets and infrastructure will be available from climate model outputs. The outputs are typically provided as long-term averages, e.g. changes in average monthly mean temperature or precipitation. However, decisions on asset integrity and safety may be based on short-term statistics or extreme values, such as the maximum expected 10 minute wind speed, or the 1-in-10 year rainfall event. In such cases, project designers or engineers should identify climate-related thresholds for the project (see Figure 4) and evaluate whether existing climate trends are threatening to exceed them on an unacceptably frequent basis. **Climate models then can be used to make sensible assumptions on potential changes to climate variables of relevance to the project or to obtain estimates of upper and lower bounds for the future which can be used to test the robustness of adaptation options.**

	**The key objective in the face of uncertainty** is therefore to define and implement design changes (adaptation options) which both provide a benefit in the current climate as well as resilience to the range of potential future climate change.

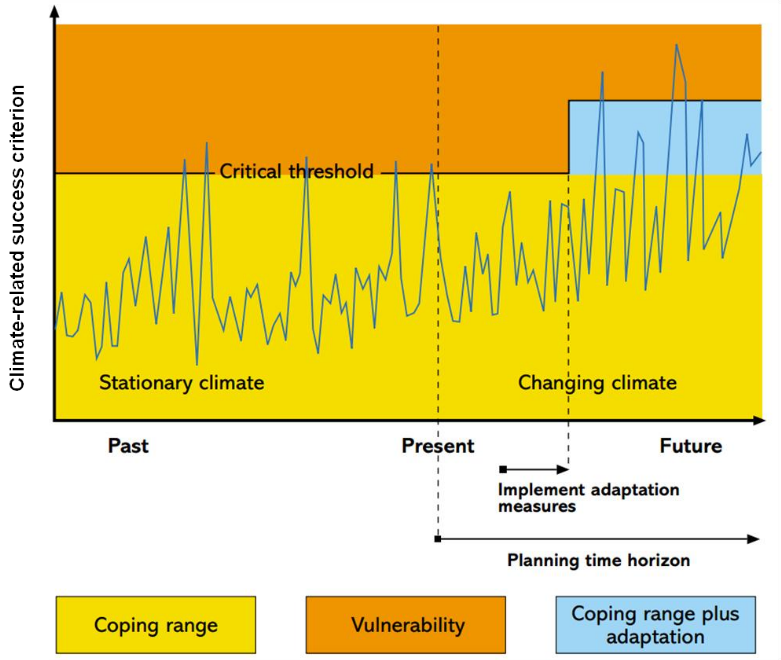


Figure 4: The relationship between coping range, critical threshold, vulnerability, and a climate-related success criterion for a project. [Source: Willows and Connell (2003)].

In light of the irreducible uncertainty about future climate change, the focus should therefore be on identifying and implementing adaptation actions which perform well both under current and possible future climatic conditions. This will have the effect of improving the 'adaptive capacity' of a development project, which is a key cornerstone of climate resilience. Thus, as an alternative strategy to the top down approach outlined above, a 'bottom up' method has been proposed[26], which can be applied to investment projects in the European Union.

The method focuses initially on finding adaptation options which reduce vulnerability to past and present climate variability (as well as 'non-climatic pressures'). It begins with an assessment of vulnerability to observed climate variability and change. Robust adaptation measures are then

[26] See Wilby and Dessai, (2010)

identified that would reduce vulnerability under current climate conditions, whilst being acceptable in other terms (e.g. technically, financially, economically, socially, environmentally). If the lifetime of the project spans several decades, then climate models can be used to establish upper and lower bounds for climate change sensitivity testing of the adaptation options. **The aim is to identify adaptation options which perform well (though not necessarily optimally) over a wide range of conditions experienced now and potentially in the future. This approach implies a shift in emphasis from identifying *optimal* actions to finding *robust* ones and is discussed further in Module 6 of the Guidelines.**

In some cases, instead of small modifications to existing plans or designs, this way of thinking may lead to completely new options being identified to address the developers' objectives, or to the objectives themselves being rethought.

A further important principle for decision-making in the face of uncertainty is to apply 'adaptive management' i.e. flexible management of the asset which can evolve and adjust as circumstances change (see the study on the Thames Estuary below).

These Guidelines have been designed to help Climate Resilience Managers apply this approach, and hence identify and implement adaptation actions which are robust to climate change uncertainties.

Detailed numerical modelling may not always be feasible for practical reasons such as time, cost and technical constraints. In some cases it may be unnecessary if an adaptation measure deliver benefits regardless of future climate, e.g. water saving measures.

[Source: Wilby and Dessai (2010)]

Box 1 Flexible adaptation

Adaptation strategies should be flexible and open-ended, especially for assets with long life spans. Regular monitoring of the environment and performance appraisal of the measures should be undertaken. A flexible approach allow different paths (adaptation pathways) to be taken depending on monitored performance and updates to climate science and attitude to risk.

Thames Estuary 2100 (TE2100) Plan, UK

The TE2100 Plan is an example of the application of a 'quasi option value' analysis to support decision-making in the face of uncertainty. The plan provides a flexible approach to adapting to flood risk in the Thames Estuary (including London) up to the year 2100. The flood defence options are dependent on changes in key components of flood risk (e.g. sea level rise, tidal surge and riverine flooding). Since there are large uncertainties attached to the key components in terms of future change, the Plan has three phases split into short, medium and long-term time periods:

1. Short term (2010 -2034): Maintaining and improving existing defences, and safeguarding space for future flood management,
2. Medium term (2035 -2070): renewal / replacement of existing tidal defences,
3. Long term (>2070): continued maintenance of existing system or construct new defence barrier.

Flexibility in the plan is delivered through:

- Allowing interventions to be brought forward in time,
- Inclusion of alternative pathways,
- Design of structures which allows modifications,
- Securing of land for new defences.

The plan will monitor ten change factors. If rapid change is detected (for example sea level rise), the plan will be adjusted accordingly and a new adaptation pathway followed.

2 Part 2: Guidelines

This part of the Guidelines:

- describes when and how Climate Resilience Managers should apply the seven modules which make up the climate resilience toolkit,
- provides guidance on the roles and responsibilities of the project manager (PM), the manager of the climate resilience process (the 'CR Manager') and the specialists involved in the project development (e.g. engineers, environmental and social specialists, economists).
- provides additional tools and technical references for specialists to apply or refer to.

2.1 Integrating climate resilience into the conventional asset lifecycle

The seven modules that make up the climate resilience toolkit are summarised in Table 2. The modules provide common methodologies which can be applied at several stages during the project development. Modules 1 to 4 have both 'high level' and 'detailed' versions. The high level versions are rapid screening exercises undertaken early in the project development cycle, and the detailed versions are applied later in the cycle, if necessary, when more information is available about the project as a basis for analysis.

Table 2: The seven modules in the climate resilience toolkit

Module no.	Module name	High level and detailed versions?
1	Sensitivity analysis (SA)	Yes
2	Evaluation of exposure (EE)	Yes
3	Vulnerability analysis (incorporating the outputs of modules 1 and 2) (VA)	Yes
4	Risk assessment (RA)	Yes
5	Identification of adaptation options (IAO)	No
6	Appraisal of adaptation options (AAO)	No[27]
7	Integration of adaptation action plan into the project (IAAP)	No

Figure 5 shows how climate resilience analyses (green boxes) can be integrated into the routine analyses performed by project developers (blue boxes). Table 4 to Table 7 below show which climate resilience analysis modules to use at each stage of the asset lifecycle, and explain the objective of using them in each context. Some of these analyses will be submitted to project investors, some of whom are increasingly playing an active role on climate resilience (see Sections 1.5 and 2.2 for further details). A case study demonstrating application of the modules is presented in Annex II.

[27] No explicit distinction is made in the guidance provided in Module 6 between 'high-level' and 'detailed' assessments. However, the former corresponds to the CBA undertaken as part of a pre-feasibility study and the latter to that for a full feasibility study. The pre-feasibility study contains shortcuts, such as the use of standard unit prices for the assessment of (financial and economic) costs and benefits.

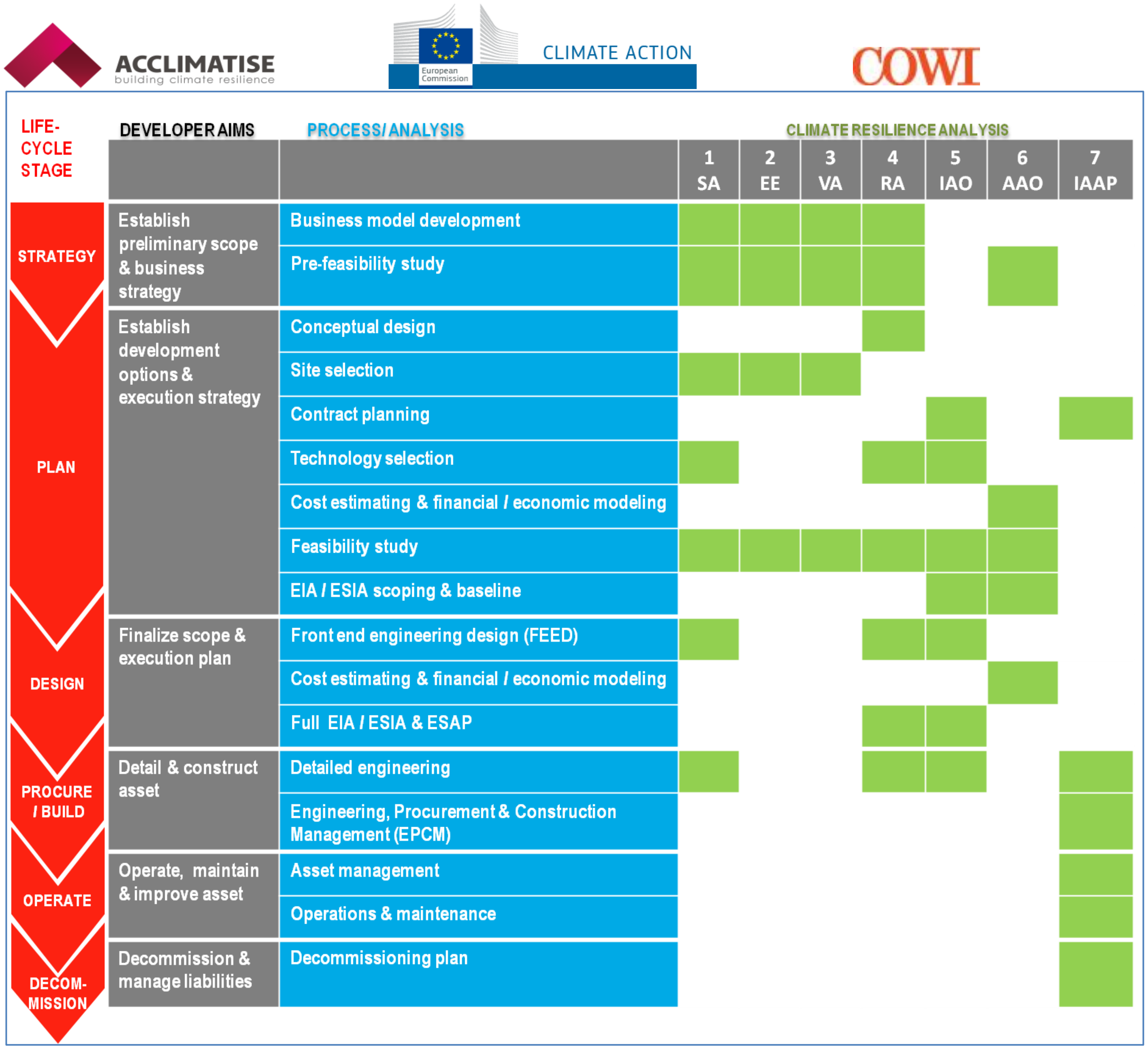


Figure 5: Integration of climate resilience analyses into a conventional asset lifecycle process. The stages in the asset lifecycle are shown in the red boxes, and the main aims of the developer at each stage are shown in grey. The blue boxes indicate the processes and analyses routinely undertaken at each stage and the green boxes show which climate resilience analyses are recommended, as per Table 4 to Table 7.

Key

1. SA Sensitivity analysis
2. EE Evaluation of exposure
3. VA Vulnerability analysis
4. RA Risk assessment
5. IAO Identification of adaptation options
6. AAO Appraisal of adaptation options
7. IAAP Integration of adaptation action plan into the project

2.1.1 Roles and responsibilities of the project team

It is recommended that the application of the climate resilience toolkit be overseen by a Climate Resilience Manager (CR Manager). The CR Manager should be appointed by the project manager responsible for overall development of the project and should be an existing member of the project development team.

The modules within the toolkit will be applied by technical experts, most (or all) of whom will already be involved in analysis supporting the project development. They may be internal or external, and may include, for instance, market analysts, engineers, economists, EIA / ESIA specialists and climate change adaptation specialists. The toolkit has deliberately been designed to complement and nest within the analyses that these experts will routinely perform as part of project development, so as to minimise the additional burden placed on project development, while still ensuring that the main objective – improved climate resilience – is achieved.

Roles and responsibilities are described below (Table 3).

Clearly, in any given project, the allocation of responsibilities may be distributed differently according to what makes most sense for the project team. Furthermore, in cases where only some of the modules are used (as per further guidance below) only the relevant responsibilities need to be fulfilled.

Table 3: Roles and responsibilities of the project team

Overall project manager for the development	**Climate Resilience Manager**	**Specialists involved in the project development (engineers, environmental and social specialists, economists etc)**
Makes the decision that the climate resilience toolkit should be applied as part of the project development cycle (either because of concerns about climate risks and vulnerabilities or by reference to Section 1.2 on the applicability of the Guidelines) Allocates resources for the climate resilience analyses		
Appoints the CR Manager to manage application of the toolkit	Oversees application of the toolkit by the specialists involved in the project development Includes requirements to use the toolkit in any relevant Statement of Work (SOW) or Terms of Reference (TOR)	
	Ensures the modules in the toolkit are applied by specialists, as summarised in Figure 5 and detailed in Table 4 to Table 7	Apply the modules in the toolkit as part of their routine analyses, as shown in Table 4 to Table 7
	Decides, in discussion with specialists, whether to move on to the next module as in Table 4 to Table 7: • for instance, Table 5 notes that Modules 1 to 6 are relevant when undertaking a feasibility study, but the CR Manager and specialists may decide that no significant vulnerabilities and risks were identified in Modules 1 to 4, and so there is no need to identify and appraise adaptation measures (Modules 5 and 6)	Discusses with the CR Manager whether to move on and apply the next module as per Table 4 to Table 7

Overall project manager for the development	**Climate Resilience Manager**	**Specialists involved in the project development (engineers, environmental and social specialists, economists etc)**
	Ensures the results of earlier climate resilience analyses are fed into later ones (as per the final column of Table 5 to Table 7) for consistency, so that cross-linkages can be understood, and to avoid duplication of effort	Review the outputs of earlier climate resilience analyses (as per the final column of Table 5 to Table 7) and consider whether they are of sufficient technical scope, depth and quality to satisfy the needs of the current analysis
	Reviews and undertakes quality assurance (QA) on the climate resilience analyses, particularly with regard to consistent use of data on current and future climate hazards (Module 2)	Provide feedback to the CR Manager on the outcomes of the climate resilience analyses Ensure their analyses are using data on current and future climate hazards consistently with other analyses (see Module 2)
	Identifies synergies and potential conflicts between climate resilience measures emerging from the different analyses	
Reviews recommendations from the CR Manager on the significance of climate vulnerabilities and risks at the end of the Strategy' and 'Plan' stages (see Table 4 and Table 5) and decides whether any further analysis is needed	At the end of the 'Strategy' and/or 'Plan' stage (see Table 4 and Table 5) may recommend to the PM that climate vulnerabilities and risks are insignificant, no further analysis is required and no climate resilience measures are needed	
Reviews recommendations from the CR Manager on the climate resilience measures to be implemented (if any) and makes the final decision on these	Presents recommendations to the project manager on the climate resilience measures to be implemented	
Prepares the financing plan for climate resilience measures	Once measures are agreed by the PM, prepares the adaptation action plan and monitoring and review plan (see Module 7)	
Ensures the measures are implemented		

2.1.2 'Strategy' stage

It is recognised that decisions made during the early stages of an investment can have the greatest impact on the ultimate business outcome and the success of the project. This is also the time when the project is least well-defined and when little information may be available as a basis for assessments. Despite this, it is essential for climate resilience that risks and uncertainties are considered in the analyses and decisions made at these stages, as indicated in Table 4 below. Bearing in mind the level of information that will be available about the project at this stage, these Guidelines recommend high-level vulnerability analyses and risk assessments are undertaken, as shown in Table 4. These will help to reduce technical, financial, environmental and social risks later in the project and begin to maximise its inherent value.

If the analyses conducted during the 'Strategy' stage (Table 4) indicate that all climate vulnerabilities and risks are insignificant, the CR Manager may recommend to the PM that no further analysis is required.

Table 4: Relevance of climate resilience to analyses and decisions made at 'Strategy' stage

Decision / analysis	Main objective of climate resilience (CR) analysis	Relevant modules
Business model development	Taking into account the lifetime of the asset, consider how current and future climate conditions could affect the project's success, e.g.: • price and availability of inputs (e.g. water, energy) • key suppliers • productivity of the asset • market demand for goods and services produced	(1 - 3) Sensitivity analysis, evaluation of exposure, vulnerability analysis (high-level) (4) Risk assessment (high-level) covering risk areas shown to left
Pre-feasibility study	Identify and articulate the high level climate vulnerabilities and risks associated with development options covering all areas of feasibility: project inputs (availability and quality), project location and site, financial, economic, operations and management, legal, environmental and social.	(1 - 3) Sensitivity analysis, evaluation of exposure, vulnerability analysis (high-level) (4) Risk assessment (high-level) (6) Appraisal of adaptation options

2.1.3 'Plan' and 'Design' stages

During these stages, the highest potential value options are evaluated and defined, prior to execution of the project, with the aim of realising the project which will bring maximum value. Owing to the improved project definition, more detailed climate resilience analyses will often be feasible and necessary, to inform the routine analyses and decisions being made, as described in Table 5 and Table 6. If the Plan and Design stages last several years (as may be the case for some large projects), the analyses and decisions may need to be reviewed occasionally to ensure that they are in line with the latest available climate change information (see for instance the monitoring approach described in Box 1, Section 1.8).

If the vulnerability and risks analyses conducted during the 'Plan' stage (Table 5) indicate that all climate vulnerabilities and risks are insignificant, the CR Manager may recommend to the PM that no further action is required, and no climate resilience measures need to be incorporated into the project.

Table 5: Relevance of climate resilience to analyses and decisions made at 'Plan' stage

Decision / analysis	**Main objective of climate resilience (CR) analysis**	**Relevant modules**	**Takes CR output from...**
Conceptual designs	Consider climate risks associated with design options.	(4) Risk assessment (high level)	Pre-feasibility study
Site selection	Ensure assessments of changing climate vulnerabilities are incorporated into site selection decisions. (This is especially important for sites in climatically-vulnerable locations.)	(1 – 3) Sensitivity analysis, evaluation of exposure, vulnerability analysis (detailed)	Pre-feasibility study
Contract planning	Ensure contractors understand need for current and future climate resilience to be incorporated into the project and of their responsibilities to deliver on this. Ensure risks associated with contractor's potential failure to deliver climate resilience will be adequately covered in contracts. Ensure that suppliers / supplies are climate resilient.	(5) Identification of adaptation options (7) Integration of adaptation action plan	Business model Pre-feasibility study
Technology selection	Identify technologies and associated design thresholds which are most sensitive to climatic conditions so that adaptation measures (e.g. extra headroom, change in technologies) can be identified early on. Understand how changing climate risks can affect choice of technology options and identify those which are resilient to current climate variability as well as the range of potential climate futures over their lifetimes.	(1) Sensitivity analysis (detailed) (4) Risk assessment (detailed) (5) Identification of adaptation options	Pre-feasibility study Conceptual designs Site selection
Cost estimating & financial / economic modelling	Ensure cost estimates to appropriate estimate class is provided for climate adaptation (resilience) measures. Undertake marginal financial / economic CBA on the adaptation measures.	(6) Appraisal of adaptation options	Pre-feasibility study Conceptual designs Site selection Technology selection
The primary outputs from the 'Plan' stage are the Feasibility Study and the EIA / ESIA (see rows below). The analyses listed above will inform these two outputs, which, in turn, will feed into the 'Design' stage (see Table 6).			
Feasibility study	Consider and articulate the climate vulnerabilities and risks associated with the development covering all areas of feasibility: project inputs (availability and quality), project location and site, financial, economic, operations and management,	(1 – 3) Sensitivity analysis, evaluation of exposure, vulnerability analysis (detailed) (4) Risk assessment	Pre-feasibility study Conceptual designs Site selection

Decision / analysis	Main objective of climate resilience (CR) analysis	Relevant modules	Takes CR output from...
	legal, environmental and social. Identify and evaluate alternatives as necessary to manage climate risks to acceptable levels.	(detailed (5) Identification of adaptation options (6) Appraisal of adaptation options	Contract planning Technology selection Cost estimating & financial / economic modelling EIA / ESIA scoping and baseline
Environmental Impact Assessment (EIA) / Environmental and Social Impact Assessment (ESIA) scoping and baseline	Identify environmental and social changes driven by climate change which may impact on the project (e.g. increased community demand for agricultural irrigation, leading to water resource conflict), and of ways that changing climate conditions could affect the environmental and social performance of the project (e.g. pollution control systems unable to cope with more intense rainfall events, leading to adverse impacts on natural environment and communities).	(4) Risk assessment (high level) (5) Identification of adaptation options	Conceptual designs Site selection Technology selection Feasibility study

Table 6: Relevance of climate resilience to analyses and decisions made at 'Design' stage

Decision / analysis	Main objective of climate resilience (CR) analysis	Relevant modules	Takes CR output from...
Front end engineering design (FEED)	Further analysis of critical design thresholds most sensitive to climate. Analyse climate risks and test robustness of critical design components to a range of climate futures.	(1) Sensitivity analysis (detailed) (4) Risk assessment (detailed) (5) Identification of adaptation options	Conceptual designs Site selection Technology selection Feasibility study EIA / ESIA scoping and baseline
Cost estimating & financial / economic modelling	Ensure cost estimates to appropriate estimate class are provided for climate adaptation (resilience) measures. Undertake marginal financial / economic CBA on the adaptation measures.	(6) Appraisal of adaptation options	Cost estimating & financial / economic modelling from *'Plan'* stage Feasibility study EIA / ESIA scoping and baseline
Full EIA / ESIA and Environmental and	Undertake detailed analysis of environmental and social changes driven by climate change	(4) Risk assessment	Feasibility

Decision / analysis	Main objective of climate resilience (CR) analysis	Relevant modules	Takes CR output from...
Social Action Plan (ESAP)	which may impact on the project and of ways that changing climate conditions could affect the environmental and social performance of the project. Incorporate measures to manage risks to the environment and society to acceptable levels.	(detailed) (5) Identification of adaptation options	study EIA / ESIA scoping and baseline

2.1.4 'Procure / Build' stage

This stage covers detailed engineering and Engineering, Procurement & Construction Management (EPCM). The final set of climate resilience measures will be confirmed. Those that need to be adopted or allowed for at this stage (in line with the principles of flexible adaptation described in Box 1, Section 1.8 and Box 2, Module 5) will be incorporated into the final designs and will form a contractual obligation for project execution.

Table 7: Relevance of climate resilience to analyses and decisions made at 'Procure / Build' stage

Decision / analysis	Main objective of climate resilience (CR) analysis	Relevant modules	Takes CR output from...
Detailed engineering	Refine climate resilience measures from FEED and embed final agreed measures within detailed engineering designs.	(1) Sensitivity analysis (detailed) (4) Risk assessment (detailed) (5) Identification of adaptation options (7) Integration of adaptation action plan	Front end engineering design (FEED)
EPCM	Ensure that the Project's Terms of Reference for sponsors, engineering design contractors / consultants explicitly states that the project is required to demonstrate current and future climate risks have been assessed, and resilience measures are to be incorporated where necessary.	(7) Integration of adaptation action plan	Contract planning Detailed engineering

2.1.5 'Operate' and 'Decommission' stages

In order to ensure that the asset continues to perform as intended over its lifetime, regular monitoring should be undertaken of the environment and the adaptation measures, to check they are providing the expected level of risk reduction. As described in Section 1.8, adaptation action plans should be flexible and open-ended, particularly for long-lived assets. Regular monitoring will alert the asset owner / operator to the need to modify the adaptation actions being implemented, based on experience.

There are currently no set standards for the frequency of monitoring and review of adaptation measures. It is generally recommended that monitoring and review are undertaken as follows:

- monitoring of data on observed climatic conditions should be undertaken on an ongoing basis, to understand the rate of change in climate parameters relevant to asset performance,
- adaptation actions should be reviewed when major new updates to climate science, impacts and adaptation are published – for instance, the Intergovernmental Panel on Climate Change (IPCC) typically publishes its assessments at approximately 5 yearly intervals,
- the performance of adaptation measures should be reviewed on an ongoing basis, and particularly following the occurrence of extreme weather events, to determine if critical climate-related thresholds were near to being exceeded.

As part of these reviews, asset managers should, where needed, update the results of Modules 1 to 4, e.g. noting any changes to the level of risks originally identified, or where new risks have emerged.

2.2 Demonstrating action on climate resilience to investors and insurers

Climate risks and resilience may be relevant to a number of the aspects of concern to investors in their project appraisals, including:

- Country risk,
- Market risk,
- Industry risk,
- Technical and operational risks,
- Environmental and social risks,
- Asset values,
- Predictability of cash flows,
- Ability to repay loans (where relevant),
- Revenue growth (where relevant)[28].

As already noted (Section 1.5), there is a growing interest among investors and insurers in seeing evidence that project developers have assessed climate change risks and vulnerabilities, and have integrated appropriate climate resilience measures into the project. Addressing these issues as part of project Prefeasibility Studies (PFS), Feasibility Studies (FS) and Environmental Impact Assessments (EIAs) / Environmental and Social Impact Assessments (ESIAs) (which are routinely provided to investors) will help to provide reassurance to investors about the resilience of the project. In many cases, investors will not invest in projects which are not insured, so links to insurers' climate change concerns are also relevant (see Section 1.5).

2.3 Modules in the climate resilience process

Overview of Modules 1 to 3

Assessing the vulnerability of individual projects to climate change is an important step in the process of identifying appropriate adaptation measures. The vulnerability analysis is broken down into Modules 1 to 3 below, comprising of a sensitivity analysis, assessment of current and future exposure, and then combining these for the vulnerability analysis. In Modules 1 to 3, guidance is provided on how this should be carried out at two levels:

[28] For further details on climate risk and financial institutions, see IFC (2010).

- High level: the first pass should be a 'high level' assessment or screening, carried out at the 'Strategy' stage (see Table 4), to provide an initial overview of exposure for a selection of possible sites and a relatively wide geographical region.

- Detailed: the second pass should be a more detailed assessment, carried out at the 'Plan' stage (see Table 5). This should be more focussed in light of the information gathered from the high level assessment.

In practice a more detailed assessment is likely to require the use of high resolution maps and specific local area models. Technical specialists will need to clearly define the level and resolution of data required in order to analyse the issues sufficiently.

1
SA

Module 1: Sensitivity analysis (SA): identify the climate sensitivities of the project

1. The sensitivity of the project should be determined in relation to a range of climate variables and secondary effects / climate-related hazards. Table 7 provides an extensive but not exhaustive list of factors to consider. Given the wide range of project types, the onus is on technical specialists to identify the variables that could be important or relevant.

Table 8: Key climate variables and climate-related hazards

Primary climate drivers:	**Secondary effects/ climate-related hazards:**
1. Annual / seasonal / monthly average (air) temperature 2. Extreme (air) temperature (frequency and magnitude) 3. Annual / seasonal / monthly average rainfall 4. Extreme rainfall (frequency and magnitude) 5. Average wind speed 6. Maximum wind speed 7. Humidity 8. Solar radiation	1. Sea level rise (SLR) (plus local land movements) 2. Sea/ water temperatures 3. Water availability 4. Storm (tracks and intensity) including storm surge 5. Flood 6. Ocean pH 7. Dust storms 8. Coastal erosion 9. Soil erosion 10. Soil salinity 11. Wild fire 12. Air quality 13. Ground instability/ landslides/ avalanche 14. Urban heat island effect 15. Growing season length

2. The sensitivity of the project options to key climate variables and hazards should be systematically assessed through the 'lens' of four key themes encompassing the main components of a value chain as follows:

    - On-site assets and processes,
    - Inputs (water, energy, others),
    - Outputs (products, markets, customer demand),
    - Transport links.

3. A score of ‘high’, ‘medium’ or ‘no’ should be given for each project type and theme across each climate variable (see Table 9). The focus is on determining the sensitivity of project options to climate variables in relation to each of the four themes. For example, a reduction in average seasonal precipitation could affect the water supply to an asset, but have little impact on important transport links. In cases where sensitivity data are available for the four themes for each project option, these can be used. However, in many cases, the assessment of sensitivity will be subjective. The following descriptions provide guidance on the determination of subjective scores:

   - **High sensitivity**: Climate variable/ hazard may have significant impact on assets and processes, inputs, outputs and transport links.
   - **Medium sensitivity**: Climate variable/ hazard may have slight impact on assets and processes, inputs, outputs and transport links.
   - **No sensitivity**: Climate variable/ hazard has no effect.

   The important climate variables and related hazards are those that are deemed **high or medium sensitivity across at least one of the four sensitivity themes**. These are the ‘essential’ factors against which potential locations for the project should be subsequently systematically mapped using GIS to determine level of exposure and finally vulnerability (see Modules 2 and 3). The assigning of sensitivity scores to project types is best carried out by experts with knowledge of the project. In many cases, projects may not be sensitive to a particular secondary climate variable, for example ‘growing season’. On the other hand, all project types will be sensitive to some hazards such as wildfires or floods.

Table 9: Sensitivity matrices (secondary effects/ climate related hazards) for example project types: road bridge, Thermal Power Plant (TPP) and waste water treatment works

		Climate variables / climate-related hazards																							
Project type	**Sensitivity theme**	Incremental air temperature increase	Extreme temperature increase	Incremental rainfall change	Extreme rainfall change	Average wind speed	Maximum wind speed	Humidity	Solar radiation	Relative sea level rise	Seawater temperature	Water availability	Storms	Flooding (coastal & fluvial)	Ocean PH	Dust storms	Coastal erosion	Soil erosion	Soil salinity	Wild fire	Air quality	Ground instability/ landslides	Urban heat island	Growing season
Thermal Power Plant (TPP)	On-site assets and processes																							
	Inputs (water, energy, others)																							
	Outputs (products and markets)																							
	Transport links																							

		Climate variables / climate-related hazards																						
Project type	**Sensitivity theme**	Incremental air temperature increase	Extreme temperature increase	Incremental rainfall change	Extreme rainfall change	Average wind speed	Maximum wind speed	Humidity	Solar radiation	Relative sea level rise	Seawater temperature	Water availability	Storms	Flooding (coastal & fluvial)	Ocean PH	Dust storms	Coastal erosion	Soil erosion	Soil salinity	Wild fire	Air quality	Ground instability/ landslides	Urban heat island	Growing season
Water treatment works	On-site assets and processes																							
	Inputs (water, energy, others)																							
	Outputs (products and markets)																							
	Transport links																							

The sensitivity matrix for the road bridge below does not include the 'inputs' sensitivity theme. This is because there are few ongoing inputs (maintenance aside) required to keep a bridge operational. In addition, 'outputs (products, markets, customer demand),' in the context of a road bridge is assumed to be the number of bridge users and, potentially, revenue (in the case of a toll bridge).

		Climate variables / climate-related hazards																						
Project type	**Sensitivity theme**	Incremental air temperature increase	Extreme temperature increase	Incremental rainfall change	Extreme rainfall change	Average wind speed	Maximum wind speed	Humidity	Solar radiation	Relative sea level rise	Seawater temperature	Water availability	Storms	Flooding (coastal & fluvial)	Ocean PH	Dust storms	Coastal erosion	Soil erosion	Soil salinity	Wild fire	Air quality	Ground instability/ landslides	Urban heat island	Growing season
Road bridge	On-site assets and processes																							
	Outputs (users and revenue)																							
	Transport links																							

Climate sensitivity	NO	MEDIUM	HIGH

Module 2: Evaluation of exposure (EE) to climate hazards

Once the sensitivities of a project type have been identified, the next step is to evaluate exposure of the project and its assets to climate hazards in the location(s) where the project will be implemented.

Module 2a: Assess exposure to baseline/ observed climate

Different geographical locations can be exposed to different climate hazards, of varying frequency and intensity (see Table 1, Section 1.2). Understanding where the exposed areas are, and how they will be affected by changing climate hazards, is important as it is at these locations where the benefits of proactive adaptation will be greatest.

1. Exposure data should be gathered for climate variables and related hazards to which assets have **high or medium sensitivity** (from Module 1). As is routinely undertaken in the design of infrastructure and assets, observed / historic climate data should be obtained for a long a period as is available. Climate is defined as "average weather conditions over a 30 year period." However, the length of available records is often insufficient to understand extreme event probability and magnitude (e.g. the 1 in 100 year flood height). In these cases, statistical analyses[29] can be performed using the observed records to calculate extreme event probability curves.

2. In each case, the information required will be made up of spatial data relating to observed data. For example, these could be data on:

    - flood risk (see Figure 7),
    - extreme temperatures,
    - heat wave frequency and
    - storm risk etc.

	Part of the process will involve deciding what constitutes high, medium or no exposure, where this is not already defined in the exposure dataset. This will relate in part to the risk appetite of the project developer which the CR Manager must agree through discussions with technical and financial specialists. For example, small changes in external air temperature may be particularly important for a certain type of project such as a climate controlled laboratory but less so for other types of projects, for example a road. The type of project should therefore determine the categories. Past records, experience of impacts on similar projects and critical thresholds from design standards are examples of tools that can be used by project teams to assign categories to exposure data.
	In some instances, the scale can be split into three bands. However, it is strongly recommended that careful consideration is given by all specialists involved in where the splits occur between bands, and whether a safety margin or weighting should applied to any of the bands in order to ensure that marginal data are accounted for in the correct banding.

[29] Extreme value theory is a branch of statistics that deals with extreme events. See http://www.mathwave.com/articles/extreme-value-distributions.html.

For the 'high level' vulnerability assessment process undertaken at the 'Strategy' stage, effort should be concentrated on gathering data for a wide range of variables. At this stage, it may not be possible to obtain regional data for all the climate variable and hazards to which the project options are sensitive.

> A useful rule is to begin looking for local data from state / regional research institutes or governmental organisations. Secondly, Europe-wide data for certain variables and hazards can be found at the European Climate Adaptation Platform (http://climate-adapt.eea.europa.eu/map-viewer). Baseline (current) global exposure to climate related risks may also be obtained from a number of other sources (see Annex III). It should be possible to upload these global datasets directly into a GIS, allowing a specific country or area to be assessed in the context of the global information. It should be noted that these global datasets are not a substitute for a local study, providing more detailed information.

Module 2b: Assess exposure to future climate

1. Where a project is classified as sensitive (Module 1) **OR** exposed (Module 2a) (with a score of medium or high) to a climate variable or hazard, an assessment should be made of how this may evolve in the future.
   - For instance, if a project is sensitive to high temperatures, an assessment should be made of how its exposure may change at future timescales relevant to the lifetime of the project. Likewise, if a project lies in an area which frequently experiences high temperatures at present, (i.e. heat waves), a similar assessment of exposure change should be made.

2. To understand how exposure may change in the future, the outputs of climate models should be examined. These provide, for instance, data on changes in temperature and precipitation (see Annex III for examples of data sources).

> The life-time of the project and its assets is a fundamental consideration when choosing the climate modelling scenario time frames (e.g. whether to use future projections for 2020s, 2050s or 2080s). For example, is the project expected to last 20, 50 years or longer?

3. Uncertainty in climate model projections should be acknowledged and recorded by presenting a summary of climate model outputs using, for example, the downscaled data provided by Climate Wizard[30] (see Annex III for other climate change data sources). This is particularly important for precipitation projections, given that the direction of change (i.e. will it increase or decrease) is often in disagreement across a number of climate models (see second column of Figure 6). Uncertainty due to emissions scenario (e.g. IPCC SRES B1, A1B and A2) should also be accounted for in a similar manner.

4. It is important that the vulnerability analyses carried out as part of the pre-feasibility study, site selection and feasibility study use the same set of climate model projections, otherwise this is an area where inconsistencies could creep in. The CR Manager will be responsible for

[30] The Nature Conservancy: Climate Wizard data portal (http://www.climatewizard.org/)

ensuring that this is managed. Similarly, the risk assessments (Module 4) will also use these climate projections.

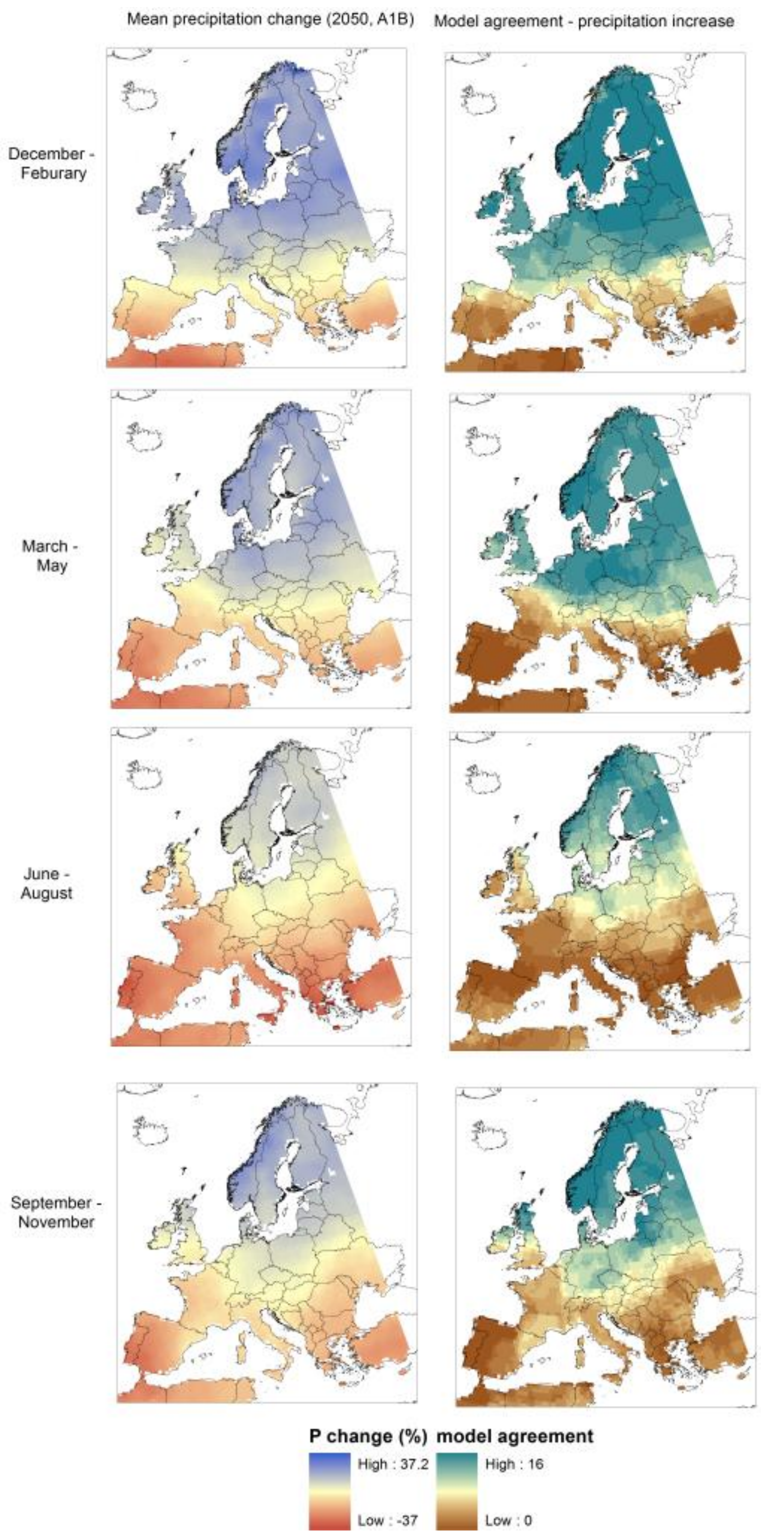


Figure 6: Seasonal projected changes in precipitation across 16 Global Climate Models for the 2050s, A1B[31].

[31] 16 IPCC CMIP3 GCM outputs, downscaled by Climate wizard, http://www.climatewizard.org, Evan H. Girvetz, Chris Zganjar, George T. Raber, Edwin P. Maurer, Peter Kareiva, Joshua J. Lawler. Applied Climate-Change Analysis: The Climate Wizard Tool. PLoS ONE, 2009; 4 (12): e8320 DOI: 10.1371/journal.pone.0008320)

It may not be possible to obtain future projections / scenarios for all the relevant variables. In these cases it may be advisable to use proxies instead. For example, future flood risk at the local scale may require detailed hydrological modelling. It is likely that robust data and modelling has not been carried out in the area of interest. In such situations, for the future exposure analysis, seasonal changes in precipitation regime in conjunction with existing flood risk exposure can be used to infer how the exposure may evolve (see Figure 6).

3 VA

Module 3: Vulnerability analysis (VA)

Module 3a: Assess vulnerability to baseline/ observed climate

Where a project is considered to have a high or medium sensitivity to a particular climate variable or hazard (Module 1), the project's location and exposure data (Module 2a) will be integrated into GIS in order to assess the vulnerability. Here, for each project site, vulnerability (*V*) is calculated as follows:

$$V = S \times E$$

where, [***S*** is the degree of sensitivity the asset has] and [***E*** is exposure to baseline climate conditions / secondary effects]. In this assessment process, the adaptive capacity of each project is assumed to be constant and equal across geographical regions.

Figure 7 shows how the location of sensitive project options can be plotted on an exposure map to illustrate where they may be vulnerable.

The sensitivity and exposure assessment for the project can now be used to provide a high level assessment of (baseline) vulnerability using a simple matrix:

1. Look back at the sensitivity scores and exposure assessment and use a matrix such as the one in Table 10 below to record the vulnerability of the project to climate variables and hazards.

2. Populate the matrix with the climate variables identified in order to get a sense of what climate variables the project is most vulnerable to, by identifying those scored as a 'medium' and 'high' level vulnerability.

Table 10: Vulnerability classification matrix for each climate variable/ hazard which could impact the project. 'Humidity' and 'flood' have been placed on the matrix as examples.

		Exposure		
Sensitivity		No	Medium	High
	No			
	Medium	Humidity		
	High			Flood

Vulnerability level	
	No
	Medium
	High

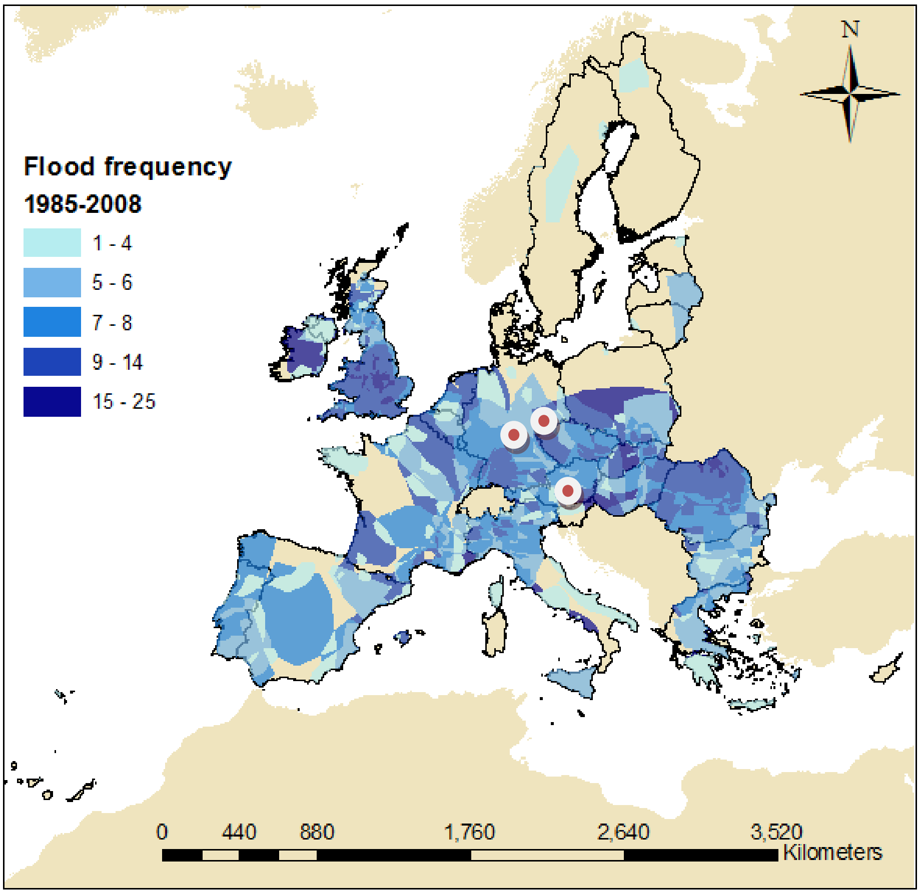


Figure 7: The spatial extent of large flood events from between 1985-2008 in the EU[32]. Example locations for a project are shown by the red dots.

[32] Data source: G. R. Brakenridge, "Global Active Archive of Large Flood Events", Dartmouth Flood Observatory, University of Colorado, http://floodobservatory.colorado.edu/Archives/index.html

Module 3b: Assess future climate vulnerability

Assuming the sensitivities of the project remain constant in the future (as evaluated at Module 1), future vulnerability (*V*) is calculated as a function of sensitivity (*S*) and Exposure (*E*) (see Module 3a). However in this case, exposure incorporates the element of future climate change. The projections of future exposure will be used to adjust the vulnerability classification matrix for each climate variable/ hazard which could impact the project (see Table 10). The uncertainty inherent in the assessment should also be acknowledged in the final vulnerability classification.

DECIDE: At this point, the CR Manager and technical specialists should decide whether all the vulnerabilities are deemed to be insignificant. If so, no further action may be needed.

Detailed vulnerability assessment (repeat Modules 1-3)

If the analyses undertaken at the 'Strategy' stage (per Table 4) indicate that the project faces vulnerabilities or risks which merit further attention, then detailed vulnerability assessments, repeating Modules 1-3, should be carried out at the 'Plan' stage (see Table 5). The decision about which vulnerabilities are to be taken forward for detailed assessment will depend on the risk attitude of the project developer. It is recommended that high vulnerabilities (per Table 10) would be subject to more detailed assessment, and that further consideration of 'medium' vulnerabilities would be at the discretion of the CR Manager and PM.

The detailed vulnerability analyses will be more focused in light of information gathered previously.

1. A more detailed sensitivity analysis is undertaken for the sensitive elements of a project's value chain identified in the high-level (screening) stage. This involves breaking the project down into smaller elements and can be aided by the use of the Risk Identification Checklist (Annex IV).

2. Exposure maps of observed climate related hazards from the high-level assessment can be supplemented by carrying out dedicated on-site inspections, preferably by teams with expertise in geosciences. In addition, more accurate and higher resolution datasets could be commissioned, for example LIDAR terrain models.

3. Revisit the vulnerability assessment matrix. The outcome of a more detailed vulnerability assessment would be a refined vulnerability classification matrix (see Table 10).

DECIDE: At this point, the CR Manager and technical specialists should decide whether all the vulnerabilities are deemed to be insignificant. If so, no further action may be needed.

Module 4: Risk assessment (RA)

The risk assessment module provides a structured method of analysing climate hazards and their impacts to provide information for decision-making. This process works through assessing the likelihoods and severities of the impacts associated with the hazards identified in Module 2, and assessing the significance of the risk to the success of the project.

The risk assessment will build upon the vulnerability analysis described under Modules 1 – 3, focussing on identifying risks and opportunities associated with the high vulnerabilities (per Table 10), and potentially also the 'medium' vulnerabilities, at the discretion of the CR Manager and PM.

However, compared to vulnerability analysis, risk assessment more readily facilitates identification of longer 'cause-effect' chains linking climate hazards to the performance of the project across several dimensions (technical, environmental, social and financial etc) and allows for the interactions between factors to be considered. This is in line with a 'systems thinking' approach, as mentioned in Section 1.7.1. Hence, a risk assessment may well identify issues which have not been picked up in the vulnerability analyses.

High level, broadly qualitative, risk assessments can be undertaken in the early phases of the asset lifecycle, with more detailed quantitative assessments conducted at later stages (as per Table 4 to Table 7):

- **High level risk assessment**: This is typically a qualitative assessment based on expert judgment and a review of relevant literature. It often involves a **Risk Identification Workshop** to identify hazards, consequences and key climate-related risks, and to agree what extra analysis needs to be done to establish the significance of risks. This may be undertaken as part of another workshop conducted by the project team.

- **Detailed risk assessments**: These are quantitative or semi-quantitative assessments, often involving some type of numerical modelling. These are best performed during smaller **meetings** or **off-line analyses**.

High level risk assessment

1. Prepare for the Risk Identification Workshop

2. At the Risk Identification Workshop identify how climate-related risks could affect the performance of the project options:
   - Review the key objectives and success criteria for the project, to help frame follow-on discussions.
   - Identify how climate-related risks could affect project performance and ability to achieve the success criteria:
     - discuss the vulnerabilities, critical thresholds[33] and climate-related risks for the most important issues identified during the Vulnerability Assessment (Modules 1-3) and with reference to the **Risk Identification Checklist** (Annex IV)

[33] Climate-related thresholds represent the boundary between tolerable and intolerable levels of risk or performance criteria for the project options, or components thereof. Thresholds may include engineering

- using the **Risk Identification Checklist,** explore the cause-effect chains linking climate hazards to aspects of project performance[34]
- record discussions, preferably on a **Risk Register** (Annex V)
- try to agree with participants the items where risks are most critical
- identify and record (on a Register) the key interactions between the engineering, operational, environmental and social risks identified
- note that climate-related critical thresholds should be defined quantitatively where possible. Where this cannot be completed at the Workshop, it will need to be done later.

3. At the Risk Identification Workshop, prioritise climate-related risks and identify risk owners:
   - Identify who is best situated to evaluate risks in the project:
     - Risk is defined as the combination of the probability of an event occurring and the consequence associated with that event. Probability and consequence scores (see Table 11 and Table 12) should be assigned in consultation with technical experts most familiar with the specific details of the project or critical project components. The CR Manager should identify who has the expert knowledge necessary to assess both dimensions of risk.
   - Assessing the significance of climate risks to performance:
     - Also referred to as 'consequence', the severity of a climate impact is the first criterion to score. A simple scale for scoring severity with five categories is detailed in Table 11.
     - Note down this score in the Risk Register.
     - Assess the probability of the climate impacts, also referred to as 'likelihood,' this estimation gauges the probability that the given consequence will occur within a certain time period (e.g. the lifetime of the project). A scoring system for probability that complements the severity scale above is shown in Table 12. Scoring these will require further reference to hazard data As collected during Module 2) and may require more detailed off-line analyses.
     - Note down the score in the Risk Register.

i	For some of the risks identified, extra **off-line analyses** will be needed after the Workshop as part of the detailed risk assessment to establish the significance of risks – for instance where they need to be quantified in operational or financial terms.

   - Assess risk by combining consequence and probability scores in the Risk Register:
     - Enter the consequence and probability scores into the Risk Register to generate a score for each risk and provide a short qualitative description of the nature of the risk.
   - Visualise risks by plotting on a Risk Matrix:
     - Transfer the consequence and probability scores for each risk to a Risk Matrix (see Annex VI). These can be in the form of numbered dots with a key describing the title of each risk. Plotting risks on a matrix helps visualise the degree of severity of the various risks and helps in prioritising them.

operational, safety/health, environmental, social, financial aspects etc (e.g. the design standard for a drainage system, to prevent overflows into the surrounding environment.).

[34] For instance, climate change may affect the length of the growing season. This in turn may impacts on fertiliser use in an area that drains into the water source for a water treatment plant, affecting its operations and operating costs.

Table 11: Assessing the magnitude of consequence across various risk areas[35]

	Magnitude of consequence				
	1	**2**	**3**	**4**	**5**
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Asset damage / Engineering / Operational	Impact can be absorbed through normal activity	An adverse event which can be absorbed through business continuity actions	A serious event which requires additional emergency business continuity actions	A critical event which requires extraordinary / emergency business continuity actions	Disaster with potential to lead to shut down or collapse of the asset / network
Safety and Health	First Aid Case	Minor Injury, Medical Treatment Case with/or Restricted Work Case.	Serious injury or Lost Work Case	Major or Multiple Injuries, permanent injury or disability	Single or Multiple Fatalities
Environment	No impact on baseline environment. Localized to point source. No recovery required	Localized within site boundaries. Recovery measurable within 1 month of impact	Moderate harm with possible wider effect. Recovery in 1 year.	Significant harm with local effect. Recovery longer than 1 year. Failure to comply with environmental regulations / consents.	Significant harm with widespread effect. Recovery longer than 1 year. Limited prospect of full recovery.
Social	No impact on society	Localised, temporary social impacts	Localised, long term social impacts	Failure to protect poor or vulnerable groups. National, long term social impacts.	Loss of social license to operate. Community protests.
Financial (for single extreme event or annual average impact)[36]	Example indicators: x % IRR <2% Turnover	Example indicators: x % IRR 2 – 10% Turnover	Example indicators: x % IRR 10 – 25% Turnover	Example indicators: x % IRR 25 – 50% Turnover	Example indicators: x % IRR >50% Turnover
Reputation	Localised temporary impact on public opinion	Localised, short term impact on public opinion	Local, long term impact on public opinion with adverse local media coverage	National, short term impact on public opinion; negative national media coverage	National, long term impact with potential to affect stability of Government

[35] The ratings and values suggested here are illustrative. The PM and CR Manager may choose to modify them.
[36] Other indicators that may be used including costs of: immediate / long-term emergency measures; restoration of assets; environmental restoration; indirect costs on the economy, indirect social costs. [EC (2010)].

Table 12: Scale for assessing the probability of a hazard[37]

1	2	3	4	5
Rare	**Unlikely**	**Moderate**	**Likely**	**Almost certain**
Highly unlikely to occur	Given current practices and procedures, this incident is unlikely to occur	Incident has occurred in a similar country / setting	Incident is likely to occur	Incident is very likely to occur, possibly several times
OR				
5% chance of occurring per year	20% chance of occurring per year	50% chance of occurring per year	80% chance of occurring per year	95% chance of occurring per year

When discussing 'probability' or 'likelihood', it is important to remember that some changes in average climatic conditions, such as seasonal temperature increases, are highly likely. Extreme climatic events, such as intense rainfall events or tropical storms, have a lower probability and changes in these are projected with lower confidence, but they may have high impacts.

For some events, particularly those related to environmental and social performance in the face of climate change, there may be considerable uncertainty regarding the likelihood of the event – for instance, conflict with local communities as competition intensifies for increasingly scarce water resources. In these cases, workshop participants will need to use their judgment to estimate likelihood, by considering current vulnerabilities and stresses. They will also need to consider how communities may themselves adapt in response to climate change. For instance, if farmers need to begin to irrigate agricultural land which has previously always been rain-fed, then this could create new tensions and conflicts that have not been apparent previously.

DECIDE: At this point, the CR Manager and technical specialists should decide whether it is necessary to identify adaptation measures to address the identified risks. If all the risks are deemed to be insignificant, no further action may be needed.

Detailed risk assessment

Having evaluated and prioritised the key climate-related risks through the high level risk assessment, detailed risk assessments stages provide the opportunity to deepen understanding of the significance of risks. The decision about which risks are to be taken forward for detailed assessment will depend on the risk attitude of the project developer. It is recommended that 'extreme' and 'high' risks (per Annex VI) would be subject to more detailed assessment, and that further consideration of 'moderate' risks would be at the discretion of the CR Manager and PM.

1. Detailed risk assessments will involve off-line analyses by specialists such as engineers to quantitatively evaluate risks taking account of climate change.

2. Within the assessments, it is important to define precisely the aspects and characteristics of the climate hazard which are most relevant to the decision. This should include:
   - magnitude and direction of change,
   - statistical basis,
   - averaging period and

[37] The scales provided here are illustrative. The PM and CR Manager may choose to change them.

- joint probability events.

3. Assessments should test the ability of the project, as currently designed, to cope with existing climate variability and the range of possible future climate hazards it will experience over its lifetime (using the output of Module 2b). They will typically require application of numerical models describing some element of the project, and will be undertaken by specialists. They may make use of climate impact models (e.g. hydrological, flood risk models etc). A range of future climates should be investigated based on a number of climate models and a range of greenhouse gas emissions scenarios. (See Annex VII for further information on how future climate change scenarios are modelled).

4. Update the Risk Register and Risk Matrix in light of the analyses.

DECIDE: At this point, the CR Manager and technical specialists should decide whether it is necessary to identify adaptation measures to address the identified risks. If the risks are all deemed to be insignificant, no further action may be needed.

5
IAO

Module 5: Identification of adaptation options (IAO)

This module helps to identify adaptation measures to respond to the climate vulnerabilities and risks that have been identified through application of Modules 1 to 4. The methodology first involves identification of options to respond to the vulnerabilities and risks, followed by qualitative and quantitative assessment of the options.

The option identification process typically involves:

1. A workshop to identify appropriate options to respond to identified risks. This can be a separate workshop, or may be a targeted session in another workshop conducted by the project team during the project development cycle.

2. Smaller meetings or off-line analyses with technical experts (engineers, etc.) to develop more detailed understanding of the pros and cons of the identified options.

3. If a workshop is to be undertaken, the CR Manager will need to ensure that the relevant technical experts are involved, and may also consider inviting external stakeholders, such as local government representatives or community groups that may assist with further elaboration of the potential options.

4. Prior to the workshop session, the CR Manager should:

    - Identify best practices adaptation examples from similar project types and become familiar with detailed guideline documents that are relevant for the specific project, using internationally recognised guidelines, business best practice, engineering standards etc. Sector-specific examples are provided in Annex VIII for illustrative purposes, and the CR Manager may adopt these as a template.

5. At the workshop, the aim is to identify options that respond to the objectives and success criteria of the project:

- For illustration, present best practice and other examples can be introduced at the start of the workshop session.
- Match your project type with the typology in Annex I.
- Use the Adaptation options checklist, (Annex X) as a brainstorming tool.
- Use the Adaptation Option Scoping Scheme (see template in Annex IX) to record the options identified that respond to the objectives and success criteria of the project.
- Refer to the list of example measures identified for some sectors in Annex VIII to help identify types of measures that may be applicable to different types of projects and the risks identified. These measures are intended for illustration purposes only and a specific project must take into account factors such as location(s), the level of protection / resilience that is acceptable, etc.

6. Consider the 'good adaptation principles' and 'guiding principles for good participatory decision-making'[38] that are valid and relevant across most vulnerable investment sectors, and that can be used to inform the selection process, namely:

   - Use a balanced approach to manage climate and non-climate risks – i.e. assess and implement the approach to adaptation within the overall context for the project.
   - Focus on identifying actions that respond to project objectives and that help to manage the priority climate vulnerabilities and risks identified from Modules 3 and 4.
   - Aim to identify measures which perform well under conditions of uncertainty (see Box 2).
   - Work with stakeholders and communities in partnerships - to ensure the adaptation options will not have unintended negative consequences for them.
   - Elaborate and communicate Specific, Measurable, Achievable, Results-oriented and Time-bound (SMART) objectives and outcomes before starting out.
   - Avoid maladaptive options (i.e. actions taken to avoid or reduce vulnerability to climate change that impact adversely on, or increase the vulnerability of other systems, sectors or social groups).

Box 2: Types of measures which perform well under conditions of uncertainty[39]

No regret options: measures that are worthwhile now (in that they would deliver net socio-economic benefits which exceed their costs) and continue to be worthwhile irrespective of the nature of future climate. Such measures will, as a rule, be cost neutral.

Low regret options: measures for which the associated costs are relatively low and for which, bearing in mind the uncertainties with future climate change, the benefits under future climate change may potentially be large.

Flexible or **adaptive management** options: these involve implementing incremental adaptation rather than undertaking large-scale adaptation at high cost in one go. This means that measures should be designed so that they make sense today, but at the same time they allow for incremental change as more information becomes available. For example, delaying measures while exploring options and working with other stakeholders to find the most appropriate solutions may be a viable approach to ensure that the appropriate level of resilience will be reached at a relevant time frame in the future. Keeping options flexible and open-ended allows them to be adjusted following monitoring and evaluation and systematic appraisal of their performance. Be careful not to exclude

[38] Based on UKCIP (2010). The UKCIP Adaptation Wizard v 3.0. UKCIP, Oxford, www.ukcip.org.uk/wizard and HM-Treasury Supplementary Green Book Guidance, Accounting for the Effects of Climate change. June 2009.
[39] Adapted from Willows and Connell (2003) and Wilby and Dessai (2010).

any alternative option paths up-front, so that the specific project design and the implementation strategy can still be adjusted and changes be brought forward in time, based on experience.

Robust adaptation options: Adaptation measures based on a flexible approach that do not preclude adaptive steps at a later stage; options that perform well though not necessarily optimally.

Win-win options: measures that have the desired results in terms of minimising the climate risks or exploiting potential opportunities, but also have other social, economic or environmental benefits; this can be measures that are introduced primarily for reasons other than climate change but also deliver desired adaptation benefits. For instance, this could be introduction of measures to improve water efficiency in agriculture, industry or buildings.

Insurance and other financial investments: Climate change risk cover through financial instruments is an alternative and/or supplement to that from investments in real assets. They may prove less robust over time as risk cover from financial intermediaries may become very expensive or not be offered at all in particularly vulnerable locations.

Soft measures: may include a wide range of measures such as reallocation of resources, behavioural change, changes to operation of a facility (e.g. changing operating rules for a hydropower plant) and might lead to real improvement in levels of resilience or adaptability by itself or in combination with other measures.

7. Initially, think widely to identify options. Annex X provides an adaptation options checklist which lists descriptions of measures that help build adaptive capacity (BAC) and in delivering adaptation actions (DAA). In some cases, rather than making small changes to the project options, more radical differences may need to be considered to address climate vulnerabilities and risks.

8. Adaptation will often involve a mix of response actions including soft and hard measures. An optimum adaptation package may also include measures that allow for exploitation of opportunities. Consider:

   - 'soft' solutions such as reallocation of resources, behavioural change, training and capacity building, institutional reforms/restructuring,
   - national and international building standards and codes with relevant technical requirements for design and construction, in order to ensure that best practice guidelines in a given sector are being used,
   - use of safety margins to cope with climate change uncertainties,
   - hard engineering solutions including retrofit to existing infrastructure, e.g. consider technical design that takes into account the accelerating rate of climate change, allowing the design of structures to be modified later on if needed,
   - the development of risk management plans incorporating risk prevention, preparedness and response measures, including relevant emergency plans,
   - risk protection via insurance or other financial instruments (purchase of options).

9. Record the long list of possible adaptation options in the Risk Register (see Annex V).

Examples of useful guidance and further reading on adaptation options

1. European Commission / European Environment Agency: CLIMATE-ADAPT Platform, Adaptation Case Studies[40]
2. 'Impacts of Europe's Changing Climate', EEA Report No4/2008, Chapter 6: Adaptation to Climate Change[41]
3. UKCIP Adaptation Wizard[42]
4. UKCIP: Identifying Adaptation Options, 2010[43]
5. Local and urban planning projects: Institute for Housing and Urban Development Studies: (CLIMACT Prio) tool Capacity building and Decision Support tool: CLIMate ACTions Prioritization[44]
6. Energy Sector: ESMAP Hands-on Energy Adaptation Toolkit (HEAT)[45]
7. Public Infrastructure Engineering Vulnerability Committee (PIEVC): PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment[46]
8. Australian Department of Environment: Climate Change Impacts & Risk Management - A Guide for Business and Government[47]

Examples of adaptation options implemented in infrastructure projects

Adapting a railway project in a permafrost region

To manage the impacts of a changing climate, engineering techniques have been used to stabilise 'warm' permafrost carrying a railway line located in northern latitudes, on the Tibetan plateau. Monitoring confirmed that the soil under the rails was particularly vulnerable: warm permafrost is very sensitive to disturbances from engineering activities, which have an immediate and direct impact on its warmth and moisture regimes. Soil temperature in the region has warmed by about 0.3°C over the past 30 years. Where human activity, such the construction of the railway has disturbed the soil, the increase in temperature is double.

The engineering techniques adopted keep the permafrost frozen well below 0°C. At the design stage, the use of the cooling technique added costs representing 1 percent of total project expenditure. The railway was itself built to withstand temperature increases of about 0.2°C and 2°C for soil and air, respectively, over the next 50 years.

[Source: IFC (2010)]

Adapting a power plant against higher air and river temperatures

The Asian Development Bank (ADB) conducted a study to identify the possible impacts of climate change on a thermal power investment project together with appropriate adaptation options. Options were identified to manage impacts from changes in air and

[40] http://climate-adapt.eea.europa.eu/sat
[41] http://www.eea.europa.eu/publications/eea_report_2008_4
[42] http://www.ukcip.org.uk/wizard
[43] http://www.ukcip.org.uk/adopt/
[44] http://www.ihs.nl/alumni/urban_professionals_information_for_alumni/climact_prio_tool/
[45] http://esmap.org/esmap/node/191
[46] http://www.pievc.ca/e/index_.cfm
[47] http://www.climatechange.gov.au/community/~/media/publications/local-govt/risk-management.ashx

	river temperature, including: • Inlet air cooling: reversing the trend of increasing air temperature by adding a cooling process to the inlet air (evaporative coolers or refrigeration chillers), • Upgrading the compressor: compensating for reduced air density through increase of flow rate using a larger model (this would represent a significant investment in both capital and operational costs), • Upgrading the heat exchanger: increasing the size of the exchanger to allow greater surface area contact between the condensate and coolant, improving the performance of the cooling water process, • Increasing the cooling water pump flow rate: passing a greater mass of fluid through the exchangers, increasing heat transfer capacity. [Source: ADB (2012)]

10. When the long list of possible adaptation options has been identified, the next step is to select a shortlist of targeted options for the specific project:
    - Identify through a screening and appraisal process a shortlist of preferred options that are environmentally, socially, technically, and legally feasible, by applying qualitative selection criteria. Criteria can be drawn from the lists in Box 2 and Box 3. The more of these criteria an option meets, the more suitable and acceptable it is likely to be.
    - It may be necessary to identify a mix of measures in order to provide the most robust overall adaptation framework which addresses all the important vulnerabilities and risks identified in Modules 3 and 4.
    - This shortlist of preferred options can then be assessed in more detail in Module 6.

Box 3: Selection criteria for screening adaptation options[48] (in addition to those in Box 2)

- **Effectiveness:** Does the option meet your overall adaptation target?
- **Robustness:** Will the option be robust under today's climate and also under a series of different and plausible climate change futures?
- **Equity:** The option should not negatively impact other areas or vulnerable groups
- **Timing:** Can the action realistically be implemented and within what timeframe?
- **Urgency:** Does the option address an existing vulnerability or a risk which is already being experienced?
- **Flexibility:** Is the option flexible in the face of uncertainties about the future?
- **Sustainability:** Does it contribute to sustainability and resource efficiency objectives?
- **Efficiency:** Do the benefits of the actions exceed the costs?
- **Costs:** Does it consider not only economic costs but also social and environmental costs?
- **Opportunities:** Are there windows of opportunity or synergies with other actions being planned that could facilitate adaptation measures being taken e.g. incorporating adaptation into the early steps of planning new construction or into infrastructure that is being upgraded anyway?
- **Synergies:** Will the adaptation option also decrease other risks than the intended climate risk, so that it helps to achieve other objectives?
- **Other factors** which may be relevant in the specific context

[48] Adapted from UKCIP (2010). The UKCIP Adaptation Wizard v 3.0. UKCIP, Oxford, www.ukcip.org.uk/wizard

11.When considering the relevant adaptation options also consider:

- by when it will be necessary to take action and why,
- what level of adaptation will be required, and
- the consequences of over- as well as under-adaptation, in order to decide on the level of adaptation required.

12.Select the options that can be implemented now.

13.Next, select those that can be implemented now or in the medium term but which would require more research and analysis, or involvement of government institutions or communities before being decided upon.

14.Prepare a planning framework for those options that may only be relevant at a later stage, and for which thorough planning and further information gathering and analysis is needed.

15.Define the timescale of the adaptation options in the project specific context, based on the lifetime of the project, and over what period the benefits of the projects are expected to be realised.

16.The options should also be checked against the objectives for the project. This is to confirm that the option will allow the objectives to continue to be met.

17.The final shortlist of climate resilience measures should be recorded in the Risk Register. Some of the measures will require further economic appraisal (Module 6) whereas others may be confirmed at this stage.

DECIDE: The CR Manager and technical specialists should now decide whether or not to proceed to appraising adaptation options (Module 6). For example, if all identified adaptation measures are 'no-regret', then no further appraisal may be required.

6
AAO

Module 6: Appraisal of adaptation options (AOO)

The objective of any standard cost-benefit analysis (CBA) as required e.g. for the EU co-funding of large scale investment projects under the Structural Funds, is to select efficient and 'optimal' options i.e. those maximising net benefits.

In the context of climate change, on the other hand, and as discussed in Module 5, the focus widens to select not only efficient options but also those that perform robustly in the context of the uncertainties associated with future climate change. In effect, defining an option selection strategy is as much about climate change risk management as it is about efficiency.

The CBA methodology for incorporating climate change presented in this module builds on a standard CBA methodology. The review of existing guidelines in the area showed that they do not go much beyond the standard methodology. Therefore, the guidance in this module proposes how the standard CBA process may be amended to take climate change issues into account. Further guidance is provided in Annex XI.

Users of these Guidelines are assumed to be familiar with this methodology and emphasis will be on suggested adjustments of the CBA in the context of investment decisions involving – in part or in full – climate change adaptation decisions. The methodology will assume that an *economic appraisal* is to be carried out, i.e. from the perspective of the country as opposed to the *financial appraisal* which covers project-promoter relevant impacts only.

	Examples of useful guidance are: • UK Treasury 'Green Book' on 'Appraisal and Evaluation in Central Government'[49] • UKCIP Costings Guidelines that build on the general approach in the Green Book[50]. • UKCIP: "Climate adaptation: Risk, uncertainty, and decision-making" [51] • The OECD guide 'Cost-benefit analysis and environment' presents an overview of the main methodological approaches and challenges in relation to the valuation of non-market impacts (use and non-use values)[52]. [**Sources**: *UK Treasury* (2003), *Metroeconomica (2004); Willows and Connell (2003); Pearce, Atkinson, and Mourato (2006)*]

In contrast to some of the previous modules, no explicit distinction is made in this module between 'high-level' and 'detailed' assessments. The former corresponds to the CBA undertaken as part of a pre-feasibility study and the latter to that for a full feasibility study. The pre-feasibility study contains shortcuts, such as the use of standard unit prices for the assessment of (financial and economic) costs and benefits.

1. Determine the project boundary

- The establishment of the project boundary defines the direct and indirect climate-related impacts and the project stakeholders to include in the option appraisal. Project preparation activities will have identified the climate change related risks and their extent. In large scale projects a risk register and/or a risk identification workshop may have been held identifying, as in standard CBA, the magnitude and likelihood of impact of the various (non-mitigated) risks (as discussed in Module 4),
- Impacts are identified in qualitative terms over the project forecast period,
- Established impacts are to be evaluated under at least one future climate change scenario (see Step 3 below). For projects with long asset lives (>20 years) more scenarios should be evaluated, to understand the implications of climate change uncertainty,

	'Impact matrices' in the UKCIP costings methodology The UKCIP costings methodology includes 'impact matrices' that help in understanding the interconnections between climate change events and sector specific impacts that

[49] www.hm-treasury.gov.uk/d/green_book_complete.pdf
[50] The UKCIP Costings Guidelines include:
- An overview report: http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Costings_overview.pdf
- Detailed guidelines for implementation: http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Costings_Implementation.pdf
- A costing spreadsheet: http://www.ukcip.org.uk/costings/costing-spreadsheet/
- Illustrative case studies, covering health, heritage building, heritage garden, highways asset management, property & insurance, and tourism : http://www.ukcip.org.uk/costings/case-studies/

[51] http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Risk.pdf
[52] http://www.oecd.org/greengrowth/environmentalpolicytoolsandevaluation/cost-benefitanalysisandtheenvironmentrecentdevelopments.htm

	may be financially and economically material at the project level. Matrices are available for the following sectors: • Coastal zones, • Water resources, • Agriculture, • Buildings and infrastructure. [Source: *Metroeconomica (2004)*]

2. Define the project forecast period and discount rate

- The *project forecast period* for the CBA should reflect the economic life of the investment project as a whole,
- As in a standard CBA, project investments are to include asset renewals for those investment components with a shorter life,
- For publicly co-funded investment projects the choice of a single *discount rate* may be prescribed at the national and/or EU level,
- If none exists, consider using declining rates over time. In environmental projects, including those involving climate change, this is the recommended approach in order to attach higher importance to longer-term intra-generational issues, as discussed in the box below.

	Discount rate The issue of discounting is important in the economic analysis of climate change, because it involves very long timescales, inter- and intra-generational issues, and potential consideration of non-marginal (catastrophic) changes to society. The choice of an appropriate discount rate for climate change decision-making has been a source of controversy and debate. Typically, in standard CBA, the same discount rate is used over the forecast period. No particular value for discounting in a climate change context is presently prescribed at the EU level. **Further reading:** *EEA (2007). Climate change: the cost of inaction and the cost of adaptation. EEA technical report No 13/2007, Pearce, D.W., Atkinson, G., Mourato, S. (2006). Cost-benefit analysis and environment: recent developments, OECD, Paris.*

3. Establish project baseline(s)

Reflecting the approach of any standard CBA, the project baseline reflects the situation 'without the project', i.e. without implementation of climate change adaptation options.

- The project baseline is the 'do-nothing' scenario for the expected future climate scenario(s),
  - At least one scenario incorporating future climate change needs to be established,
  - Projects with long forecast periods (>20 years), should include more climate change scenarios and therefore more project baselines,
  - The baseline is to incorporate the expected impacts of any climate change mitigation policies,
- Impact matrices may assist in the quantification of the outcome indicators of the baseline(s).

4. Identify costs and benefits of the various options

- Draw up a short list of technically and legally feasible options/option mixes based on the guidance in Module 5,
- As in a standard CBA, ensure the 'do nothing' option is included,
- In preparing the strategy consider the nature of climate change risks facing the project:
    - If risks are gradually increasing over time only, then a time-phased option implementation strategy, with gradually increasing risk protection levels is cost-efficient. It will also be feasible if the project design has built-in flexibility for later upgrades ('quasi-options'), i.e. where upgrades take place later when more is known about the level of climate change risk[53].
    - If the adaptation measures are to hedge against increasing extremes in climate, then high levels of risk protection are likely preferable, as well as cost-efficient, early on
    - If design flexibility is limited, as it is in many major construction projects, climate change adaptation measures will need to be implemented up-front,
- Identify other market impacts (costs and benefits) of the project as well as secondary and non-market impacts within the project boundary for the project scenario(s),
    - The risk protection from the options should result in avoided future costs for the promoter and possibly other stakeholders e.g. as to damages and production stoppages,
    - Consider also any negative impacts on other stakeholders,
    - Address also whether use and non-use values of the project are to be included – as is common in environmental projects,
- Estimate the number of physical units of identified costs and benefits for the forecast period.

5. Value costs and benefits of adaptation options

- As in any investment project, seek to establish investment and operating costs of the options,
    - This is not feasible when climate change resilience measures are an integral part of the project design. In those cases, the lifecycle costs of options with differing protection levels may be examined as to the risk reduction vs. cost trade-off (see Step 8),
- Establish unit values for other costs as well as project benefits,
- The benefit-transfer method could be used for estimating project benefits to the promoter in the form of avoided future costs and market impacts on other stakeholders (historic costs elsewhere) but this method is to be used with caution,
- Value non-market impacts according to standard methodologies for environmental projects,
- Calculate the Economic Net Present Value (ENPV) of the various options/option mixes in the identified scenario(s) over the project life. The standard incremental approach is applied comparing the costs and benefits with and without climate change adaptation,
- If the strategy includes quasi-options with deferred adaptation measures, the valuation is to be based on a decision tree approach. This is to include the likelihood that further protection measures are needed in the future, meaning also that its timing must be estimated. The weighted average cost of the adaptation now and in the future may then be determined.

i	In the cases, rare so far, where **probabilistic scenarios** are available (e.g. the UKCP09 climate projections for the UK), these can be used to undertake a more detailed statistical analysis of estimates of the expected outcomes (expected, probability weighted ENPV) across multiple climate change scenarios.

[53] The TE2100 project presented in Box 1 is an example of the use of quasi-options.

6. Assess hedging effectiveness and certainty of impact of options

- Review the options/option mixes under consideration as to whether they are all equally effective in terms of reducing exposure to climate risks (i.e. 'hedging effectiveness') and the certainty of their risk-reducing impact,
    - When the adaptation options under consideration are not likely to be equally effective at reducing risk exposure, an assessment of their economic efficiency (ENPV) alone is not sufficient as a basis for choosing between them,
    - Options in the control of the decision-maker through investments or operational improvements are more certain in their impacts than 'soft' options (e.g. for bringing about behavioural changes in consumers),
- Compare the hedging effectiveness and certainty of impact with the associated costs,
- If the trade-off between risk reduction and the cost of an option shows there to be excessive uncovered (open) residual climate change risk, introduce supplementary adaptation measures with the option. If none are feasible, the option is not attractive and should not be further considered.
- If the certainty of option effectiveness relative to costs is not acceptable, then the exclusion of the option from further appraisal should be considered.

7. Assess distributional impacts

- Steps 1 and 4 addressed the project impacts (positive/negative) on stakeholders other than the promoter,
- Assess the extent of these impacts separately,
- Decide whether they are of a size such that they should be explicitly considered in the decision rule for option selection,
- If so, determine how these distributional issues are to incorporated:
    - by assigning (subjective) weights to the costs and benefits for these stakeholders in the ENPV calculation, or
    - by having distributional impacts as an explicit (and subjective) decision-making criterion.

8. Determine the decision rule for option selection

Implementation of adaptation options is an essential part of climate change risk management. The selection of options which are not all equal in terms of hedging effectiveness involves risk taking. In addition, not all options will necessarily perform equally well under different key assumptions or alternative climate change scenarios. The decision rule should thus be set in a risk management context. Furthermore, distributional issues may need to be integrated (per Step 7).

- First establish the attitude of the decision-maker towards climate change risk:
    - If the decision maker is a high-risk taker ('risk-lover') then only economic efficiency matters and the option strategy with the highest ENPV should be selected,
    - If the decision maker is risk-neutral, then the option with the highest (simple) average ENPV from relevant sensitivity testing in the one-scenario case, or from across scenarios in the multi-scenario case should be chosen,
    - If the decision maker is risk-averse, then the distribution of the ENPV values from conventional sensitivity testing or from scenario simulations must be taken into consideration such that options that perform robustly – offering better risk protection – relative to their costs are selected,

- Next, to the extent required, integrate any other aspects not related to economic efficiency and risk attitude in the decision rule, such as distributional issues or social acceptability. This would be relevant for large-scale projects with a comparatively wide project boundary,
- Decide on the weights to assign in the (then required) Multi-Criteria Analysis (MCA) decision rule,
- For projects with risk-neutral or risk-averse decision makers, it may be useful to map the ENPV values from the sensitivity and/or scenario testing in a pay-off matrix (see example in Table 13 below),

Table 13 Example of pay-off matrix of the ENPV of appraised options

	ENPV	**No climate change (optional)**	**Climate scenario 1**	**Climate scenario 2**	**Climate scenario [...n...][54]**
Adaptation options	'Do- nothing' option				
	Adaptation action 1				
	Adaptation action 2				
	Adaptation action [...n...]				

[Source*: Adapted from Metroeconomica (2004)]*

- Finally, based on the established decision rule the adaptation options/option mixes may be ranked and the 'best' one selected for implementation with the project.

Regardless of project type and size, the most important single change when performing a CBA for projects involving climate change adaptation measures is the decision rule. This is in recognition of the fact that the risk-averse decision maker (as most users of these guidelines will be in relation to climate risks) will wish to select options as part of a risk-return trade-off strategy, rather than those that offer the maximum economic efficiency which is targeted in a standard CBA.

DECIDE: At this stage, a decision can still be made to choose the 'do nothing' option (i.e. not to adapt). If this is the case, it will not be necessary to proceed with the development and integration of an adaptation action plan (Module 7).

7 IAAP

Module 7: Integration of adaptation action plan (IAAP) into the project

1. Following the options appraisal (Module 6), decide on the modifications to the technical project design and management options, as relevant. Integrate the climate resilience measures in project design and into contracts at the 'Procure/Build' stage of the project appraisal cycle (see Table 7),

2. Undertake the following actions when designing an implementation plan for the confirmed climate set of resilience measures:

    - Identify clear roles and responsibilities for the relevant stakeholders who are involved, (particularly contractors and suppliers), clear descriptions of how the adaptation option(s) should be implemented (e.g. via supplier contracts, through risk transfer to insurers) and what they will require in terms of resources (staff, technological needs, financial needs) to implement,

[54] In order to capture the range of uncertainties associated with climate change projections due to climate model and emission scenario uncertainty, for longer-term projects it is always recommended to investigate a range of climate change scenarios based on multiple climate models and emission scenarios.

- Identify the actions that need institutional and community cooperation to implement. For these cases, plans for consultation and communication as well as a timetable for each action,

3. Prepare a plan for how to finance the measures

- State explicitly how the project will manage climate risks and vulnerabilities,
- As far as the financing of high cost (investment) options are concerned the procurement of finance is no different than in standard project finance. The project feasibility study report supporting the financing request will describe how uncertainty and risk is being addressed. This will also help to demonstrate climate resilience to financiers,
- With respect to the financing of the low cost (soft and operational procedures changes) options, the only financing source for such increase in operating cost will be the clients of the operating company, e.g. water, energy consumers etc. In the case of soft options they may possibly be included in a co-financing request for high cost options but not as a separate request. (As a general rule, external financiers do not finance operating costs, but rather investments in fixed assets. Hence, they will also not generally finance any increases in such operating costs that may be associated with the implementation of 'low cost' options for operational improvements.)

4. Prepare a plan for monitoring and response

- Review and monitor on an ongoing basis whether the adaptation decisions return the expected level of resilience / protection:
  - Carry out monitoring and systematic appraisal of the performance of measures,
  - Design a 'checklist' or a monitoring and evaluation plan to ensure that lessons are learned which can inform the continuing process of ensuring resilience. This plan should include relevant and specific indicators on the impacts, outcomes and outputs in order to consistently collect the lessons learned at project level. The evaluation of the project performance should be set up against a baseline describing the actual state of conditions before the investment project starts. Progress is then measured by comparing the indicators at a given milestone at a point in implementation with the original baseline,
  - Review the continued relevance and effectiveness of the adaptation decisions by adopting a continued improvement approach,
- Identify whether adjusting actions need to be made:
  - Having measured the performance of the project, consider the extent to which it delivers the expected and desired results,
  - Decide whether to accept observed impacts including losses, consider whether to off-set losses by further insurance, and/or
  - Carry out adjustments to the specific project design and the implementation strategy as needed, again without hindering further adaptive measures in the future.

Part 3: Annexes

Annex I: Typology of investment / project types

Main project category	Sub category	Project type
Energy	Electricity production	Conventional TPP
		Combined cycle TPP
		Gas turbines
		Large hydropower
		Small hydropower
		Wind
		Solar
	District heating	Fossil fuel DHP
		Biomass DHP
		Geothermal DHP
	Cogeneration	Fossil fuel CHP
		Biogas CHP
	Electricity	Power transmission networks
		Power distribution networks
	Fuel	Gas pipelines and facilities
		Oil pipelines and facilities
Buildings	Commercial buildings	Commercial facilities (e.g. shopping malls, warehousing, office buildings)
		Hotels and tourism facilities, etc.
	Domestic buildings	Domestic housing
	Public buildings	Educational infrastructure
		Hospitals and other healthcare infrastructure
Infrastructure: Transport Environmental Infrastructure Information and Communication Technology		Railways
		Motorways & roads
		Bridges
		Airports
		Ports
		Inland waterways

Main project category	Sub category	Project type
		Waste water treatment
		Drinking water supply
		Solid waste management
		Flood protection
		Cable ICT networks
		Wireless ICT networks
Industry	Various	Electrical equipment, appliances
		Fabricated metal product manufacturing
		Furniture and related products
		Machinery and other industrial
		Transportation equipment
		Plastics and rubber
		Textiles, apparel, leather
	Chemicals	Basic Chemical Manufacturing
		Other chemicals
		Paint and Adhesives
		Pesticides, fertilizers
		Petroleum & coal products
		Pharmaceuticals
		Resins, synthetic rubber
		Soaps
	Wood processing	Wood products
		Pulp and paper
	Non-metallic mineral product manufacturing	Brick, tile and ceramic
		Cement
		Glass

Annex II: Case study demonstrating application of the Guidelines to costs and benefits of flood prevention in Copenhagen

The City of Copenhagen has undertaken studies to support their risk assessment and long term climate adaptation planning. The results of the assessments clearly demonstrate the huge benefit of undertaking such risks assessments and analysing alternative adaptation options in an integrated manner. The assessment process included activities that are very similar to the Guideline's seven modules and so the example can illustrate the application of the modules.

Module 1-3: High level assessment

The process included first a high level assessment of the type of climate change impacts that could have an effect on buildings and infrastructure in Copenhagen. This assessment identified that the most relevant hazards were related to increasing sea level and extreme rainfall events and therefore these events were assessed in more detail.

Module 1: Sensitivity analysis (SA)

The sensitivity of different types of buildings and infrastructure to flooding events were assessed. This included mapping of the different type of buildings and infrastructure and assessing the potential damage that a flooding event could cause each type of building or infrastructure. This was undertaken for all potential damages and summarised for "cells" of 100 x 100 meters.

Module 2: Evaluation of exposure (EE)

The likelihood of current and future extreme rainfall events and increasing sea levels were assessed for one key climate change scenario (encompassing one greenhouse gas emissions scenario (IPCC A2 – see Annex VII) and one downscaled global climate model. For that scenario the number of specific events (e.g. extreme rainfall events) was estimated over a 100 year period. The study also included qualitative sensitivity tests for alternative climate change scenarios.

Module 3: Vulnerability analysis (VA)

Based on detailed hydrological models the vulnerability for different events (heavy rainfall and increased sea levels) was assessed and the total average likelihood of flooding was calculated for each cell. Figure 1 is a map of Copenhagen where the vulnerability is illustrated. The areas marked with red are most vulnerable to flooding over the 100 year period.

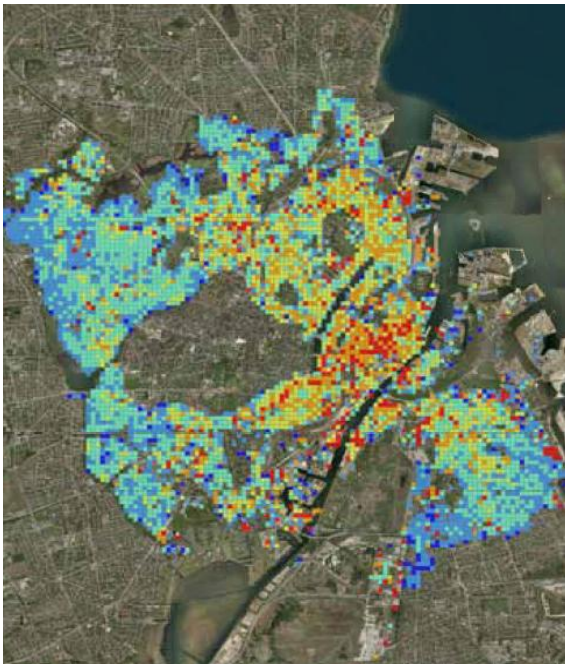


Figure 8: Vulnerability to flooding in Copenhagen from extreme rainfall events

High vulnerability

Low vulnerability

Module 4: Risk assessment

Economic damage costs were estimated based on the damage to buildings, stations, roads, etc over a 100 year period for each cell. This allowed an estimation of the total damage costs. The results are illustrated in Table 13 and Table 14 below. As explained above, the estimates were made for only one climate change scenario.

Module 5: Identification of adaptation options (IAO)

Alternative adaptation measures were identified and assessed. These included construction of dikes and changes to stormwater management systems (for example alternative retention solutions using parks and green areas to retain water, and expansion of sewer network capacity).

Module 6: Appraisal of adaptation options (AAO)

In the adaptation option analysis, alternative scenarios with and without adaptation options were assessed. The changes in total damage costs were then compared to the costs of the adaptation options. The overall estimates of the cost-benefit of the measures were made for a 100 year period.

For rising sea levels, only one package of adaptation measures was defined and included in the numerical analysis. Table 14 shows the damage cost with and without adaptation measures and the cost of the measures related to an increase in sea level. The net gain was calculated as approximately DKK 16 billion (around 2 billion EUR). In other words, it is clearly cost-efficient to implement the measures against rising sea levels.

Table 14: Net present values for rising sea levels (1 meter in 100 years) in million DKK

Alternative scenarios	**NPV**
Damage cost without measures	20,098
Damage cost with measures	189
Gain	19,908
Cost of measures	3,997
Net gain	15,911

Regarding extreme rainfall, the possible adaptation options vary significantly in costs compared to the benefits they achieve. Table 15 illustrates the importance of undertaking an options analysis and selecting the measures that achieve the best overall economic results.

Table 15: Net present values for extreme rainfall in million DKK

Alternative scenarios	**NPV**
Damage cost without measures	15,552
Damage cost with cheapest measure (non-return valves)	4,316
Damage cost with most expensive measure (increased sewer network capacity)	5,458
Cost of cheapest measures (non-return valves)	3,001
Cost of most expensive measure (increased sewer network capacity)	10,372
Net gain - cheapest measure	8,235
Net gain - most expensive measure	-278

This example shows that there is a considerable gain in preventing flooding for the cheapest measure, but not for the most expensive one. Choosing a cost-effective measure can lead to a net gain of about 8 billion DKK (a little more than 1 billion EUR).

Module 7: Integration of adaptation action plan (IAAP) into the project

The results of the assessments were included in an adaptation plan and in the specific action plans for municipal organisations and companies that are responsible for the different measures, notably the water and wastewater utility.

Source: Københavns Kommune 2011, *Københavns Klimatilpasningsplan (The Adaptation Plan for City of Copenhagen).*

Annex III: Geographic exposure mapping portals with European coverage

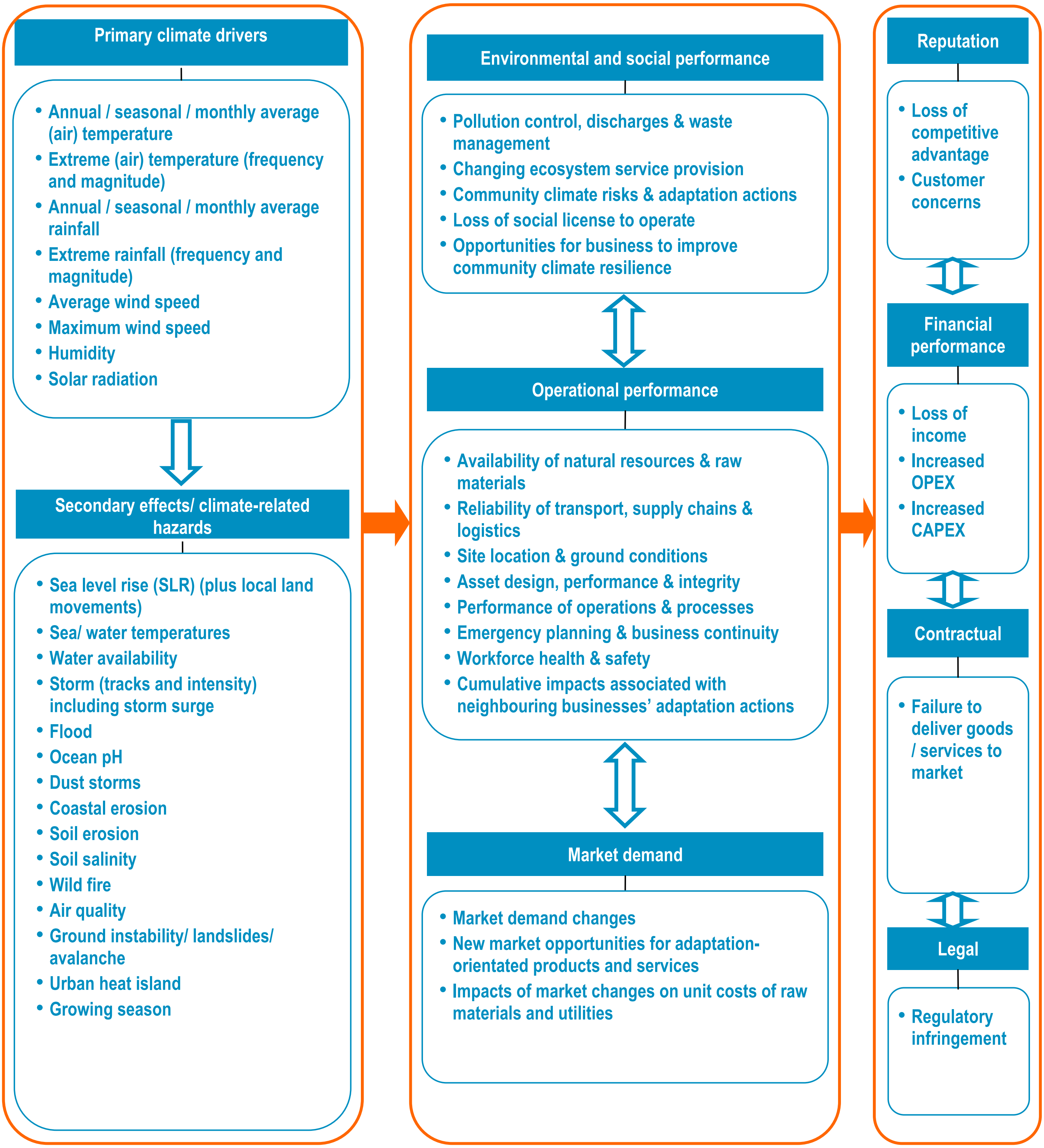
Name	Link	Short description	Climate variables covered	Overall time period covered	Number of climate models used	Statistical nature of data given	Emissions scenarios	Other features
European Commission/ European Environment Agency: CLIMATE-ADAPT Platform	link	Provides access to climate related observations and projections of climate change impacts, vulnerability and risks from ClimWatAdapt, ESPON Climate, JRC-IES and ENSEMBLES.	Extreme temperatures, water scarcity, flooding, sea-level rise, droughts, storms, ice and snow	2020-2100	Multiple (not specified)	Not specified	Multiple (not specified)	Option to look at sector level; highest resolution; accessible interface.
World Bank: Climate Change Knowledge Portal	link	Provides a central hub of information, data, maps and reports about climate change around the world – data available on a country level.	Precipitation, temperature	2020-2100	9	Means; percentage of change	A2, B1	Easy to use, historical data and future projections; sub-national resolution
The Nature Conservancy: Climate Wizard	link	Enables technical and non-technical audiences alike to access leading climate change information and visualize the impacts anywhere on Earth	Precipitation, temperature	2050s, 2080s	16 (+ensemble averages and scenarios)	Averages; percentage of change	A2, A1B, and B1	Easy to use; high resolution available with ensemble data. Options to animate data or import to ArcGIS.
Intergovernmental Panel on Climate Change: Data Distribution Centre	link	A common and easily accessible set of information relating to climate change scenarios for impacts and adaptation assessments	precipitation, pressure, humidity, temperature, wind	2030, 2040s	8	Mean anomalies, mean climatologies	multiple	Global coverage, varied resolution; produces maps for export; includes more variables than just precipitation and temperature

Further details of the geographic exposure data which are available in the above portals is provided in an Excel tool accompanying this Annex, called 'Annex III Supplement'.

Other useful data sources:

- Water resource availability: http://insights.wri.org/aqueduct/2011/10/closer-look-aqueducts-new-global-water-stress-maps
- Flood: http://www.dartmouth.edu/%7Efloods/Archives/index.html
- Slope instability:
    - http://preview.grid.unep.ch/index.php?preview=data&events=landslides&lang=eng
    - Wild fire: http://preview.grid.unep.ch/index.php?preview=data&events=fires&lang=eng
    - Tropical cyclone risk: http://preview.grid.unep.ch/index.php?preview=data&events=cyclones&lang=eng

Annex IV: Risk Identification Checklist



Annex V: Example Risk Register

This example risk register is also provided as an Excel tool accompanying this Annex, called ‘Annex V Supplement’.

Example Risk Register: Climate-related risks to projects / investments

Project / asset Name: Insert
Climate Risk Workshop: Insert date
Attendees: List attendees

				RISK SCORE			
REF	CATEGORY	CLIMATE-RELATED VULNERABILITIES, SENSITIVITIES AND CRITICAL THRESHOLDS	CLIMATE-RELATED RISKS	L	I	L x I	C
Temperature-related issues							
1						0.0	
2						0.0	
3						0.0	
4						0.0	
5						0.0	
Precipitation-related issues							
6						0.0	
7						0.0	
8						0.0	
9						0.0	
10						0.0	

PROBABILITY / LIKELIHOOD (L): 1 = Rare, 2 = Unlikely, 3 = Moderate, 4 = Likely, 5= Almost certain
MAGNITUDE OF CONSEQUENCE / IMPACT (I): 1 = Insignificant, 2 = Minor, 3 = Moderate, 4 = Major, 5 = Catastrophic
RISK SCORE = L x I (Before Adaptation)

EXISTING RISK MANAGEMENT MEASURES / CONTROLS	PROPOSED / POTENTIAL ADAPTATION ACTIONS	OWNER(S)	DUE DATE(S)	COMMENTS

Annex VI: Example risk matrix

By way of example, the risk matrix below has been partially filled in for climate-related risks to energy assets in Albania[55].

				Magnitude of consequence				
				Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood / probability	5	Almost certain	95%			6	3, 4, 7	1, 2
	4	Likely	80%				5	
	3	Moderate	50%			8		
	2	Unlikely	20%					
	1	Rare	5%					

Key

Risk level

Extreme

High

Moderate

Low

Risk no.	Description of risk
1	Higher peak energy demand in summer due to higher temperatures could lead to lack of power capacity.
2	Less summer electricity generation from hydropower facilities due to reduced precipitation and runoff could reduce energy security.
3	EU carbon trading schemes could add cost to thermal power generation.
4	Changes in seasonality of river flows combined with mismanagement of water resources could decrease the operating time for small hydropower plants, resulting in decreased production.
5	Increased CAPEX / OPEX due to climate change could lead to reduced shareholder value.
6	Higher peak summer demand across the region could increase import prices and reduce supply.
7	Paucity of hydromet data makes it difficult to manager water resources and optimise operation of hydropower plants.
8	Sea level rise could lead to increased coastal erosion potentially affecting energy assets in the coastal region such as ports for oil export.

[55] The example risks shown on this matrix are taken from a World Bank study of climate vulnerabilities and risks for Albania's energy sector (World Bank, 2009).

Annex VII: Modelling future climate trends using Global Climate Models (GCMs)

Projections of possible future trends in global climate change are primarily provided by general Circulation Models, (GCMs), also known as Global Climate Models. GCMs are global-scale climate models that apply a series of equations based on established laws of physics and chemistry to the earth's atmosphere and oceans. GCMs are useful to predict trends in primary climate drivers such as temperature and precipitation and other proxy climate change trends such as sea level rise or the frequency of tropical storms.

The level of future climate change depends to some extent on the amount of greenhouse gas (GHG) emissions that are emitted now and in the future. GHG emissions are, in turn, dependent on demographic development, socio-economic development and technological change. All of these variables carry levels of uncertainty. In order to capture this uncertainty different GHG emissions scenarios are used and are fed into the GCMs. There are four main groups of emissions scenarios used by the IPCC to date, termed A1, A2, B1 and B2. Table A1 summarises the socio-economic 'storyline' behind each emissions scenario.

Table A1: Descriptions of the four main groups of emissions scenarios[56]

Scenario	Description
A1 group	The A1 scenario group describes a future of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1 group divides into three scenarios that describe alternative directions of technological change in the energy system: Fossil fuel intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).
A2 group	The A2 scenario group describes a heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
B1 group	The B1 scenario group describes a convergent world with the same global population as in the A1 storyline - peaking in mid-century and declining thereafter - but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
B2 group	The B2 scenario group describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 groups. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Climate models provide projections based on a unique understanding how physical changes in the earth's climate will affect temperatures, rainfall levels and, with less certainty weather patterns. As a result of this, there is frequent disagreement between models. GCM climate change scenarios are therefore best presented as a composite of multiple models. In general, it is considered that the

[56] Source: IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

greater model agreement there over a particular change, the greater confidence can be assigned to the result (Raper et al (1996), (IPCC, 2007b). Table A2 shows the GCMs that were used in the IPCC Fourth Assessment (IPCC, 2007b). Each model has a unique structure, different levels of spatial resolution and assumptions.

Table A2: Global Climate Models used in the IPCC Fourth Assessment report[57]

Centre	Model	GHG + A Forcing
Beijing Climate Centre	BCCCM1	1PTO2X, 1PTO4X
Bjerknes Centre for Climate	BCM 2.0	SR-A2, SR-B1
Canadian Centre for Climate Modelling and Analysis (CCCMa)	CGCM3T47 (T47 Resolution)	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
Canadian Centre for Climate Modelling and Analysis (CCCMa)	CGCM3	SR-A1B, SR-B1
Centre National de Rescherches Meterologiques	CNRMCM3	1PTO2X, 1PTO4X, COMMIT, SR-A1B, SR-A2, SR-B1
Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO)	CSIROMk3	1PTO2X, SR-A2, SR-B1
Max Plank Institute for Meteorologie	ECHAM5OM	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
Meteorological Institute, University of Bonn Meteorological Research Institute of KMA Model and Data group at MPI-M	ECHO-G	1PTO2X
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLCM2.0	COMMIT, SR-A1B, SR-A2, SR-B1
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLCM2.1	COMMIT, SR-A1B, SR-A2, SR-B1
GISS	GISSE-H	1PTO2X, SR-A1B
GISS	GISSE-R	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
UK Met. Office	HADCM3	SR-A1B, SR-A2, SR-B1
UK Met. Office	HADGEM1	SR-A1B, SR-A2
1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, SLAB, SR-A1B, SR-A2, SR-B1	INMCM3.0	1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, SLAB, SR-A1B, SR-A2, SR-B1
Institute for Numerical Mathematics	INMCM3.0	1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, SLAB, SR-A1B, SR-A2, SR-B1
Institut Pierre Simon Laplace	IPSLCM4	1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, PDCTL, SR-A1B, SR-A2, SR-B1
National Institute for Environmental Studies	MICROC3.2 hires	SR-A1B, SR-B1, Extremes (AMIP, SR-A1B, SR-B1)
Meteorological Research Institute, Japan Meteorological Agency, Japan	MRI-CGCM2.3.2	SR-A2, SR-A1B, SR-B1
National Institute for Environmental Studies	MICROC3.2 medres	SR-A1B, SR-A2, SR-B1, Extremes (AMIP, COMMIT, SR-A1B, SR-A2, SR-B1)
National Centre for Atmospheric Research (NCAR), USA	NCARPCM	COMMIT, SR-A1B, SR-A2, SR-B1
National Centre for Atmospheric Research (NCAR), USA	NCARCCSM3	SRA1B, SR-A2, SR-B1

[57] Adapted from: IPCC. 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Annex VIII: Illustrative examples of adaptation options by project category

Project category	Climate variable and climate related hazards	Geographical vulnerability	Climate change impacts	Adaptation option
Transport Infrastructure	Change in temperature Change in precipitation Extreme events Increased sea level rise and storm surges Increase in drought and wildfires Increase in wind speed and storms	Low lying areas Flood prone areas Coastal zones River beds Valleys Lowland Steep slopes Flat land and delta regions Mountains	May impact road pavements May impact road foundations May impact critical transport infrastructure May impact coastal transportation infrastructure May result in damage to infrastructure and infrastructure failures	Subsurface conditions Material specifications Standard dimensions Drainage and erosion Protective engineering structures (dikes, seawalls, etc.) Maintenance planning and early warning Increased maintenance Alignment, master planning and land use planning Environmental management

Project category	Climate variable and climate related hazards	Geographical vulnerability	Climate change impacts	Adaptation option
Environmental Infrastructure	Increased flood risk from coastal storm surges, river levels, increased precipitation and rising ground water Decrease in precipitation and increased evaporation from higher temperatures Increased frequency of hurricanes, cyclones and typhoons Increased frequency and intensity of heat waves, drought and wildfires Extreme temperature fluctuations	Climate regions Local topography Coastal zones River beds Valleys Lowland Steep slopes Flat land and delta regions Mountains	Damages to human settlements, production facilities, infrastructure, agricultural areas and human health Soil erosion and landslides Lack of water for drinking, hydropower, agriculture etc. Reduced water quality	Design in accordance with range of future climate conditions Retention and diversion of water Dam, embankment, barrage Store water for irrigation, infiltration and hydropower Re-alignment and/or upgrading of infrastructure Greening of urban areas Spatial planning Insulation Alert and emergency systems Environmental management

Annex IX - Scoping Adaptation Options[58]

Key climate change risk	Type of option (technical/ operational/ strategic)	Options to reduce likelihood/ options to manage the consequence	Action	Risk/action could be dealt with by	Additional (co-shared) benefits	Responsible	In co-operation with	Deadline for action
Key climate change benefit	**Type of option (technical/ operational/ strategic)**	**Options to reduce likelihood/ options to manage the consequence**	**Action**	**Benefit/ action could be dealt with by**	**Additional (co-shared) benefits**	**Responsible**	**In co-operation with**	**Deadline for action**

58 Based on BACLIAT Adaptation Option Tool (http://www.ukcip.org.uk/bacliat/).

Annex X: Adaptation options checklist

Adaptation type	**Description / examples**
Building adaptive capacity (BAC)	
Research and analysis	• Research and analysis is useful to reduce uncertainties prior to investing in costly risk management measures • Develop better understanding of the relationships between climate-related factors and the performance of assets • Develop in-depth integrated climate change risk assessments • Develop higher resolution data on future climate variability and climate change • Undertake cost-benefit analyses of risk management measures incorporating uncertainty analysis
Data collection and monitoring	• Monitor impacts of climate-related factors on performance of existing Assets • Monitor new developments in climate change science
Changing or developing standards, codes, risk registers etc	• Amend standards, codes of practice for new Projects to ensure they are resilient to / take account of changing climatic conditions. • Incorporate climate-resilience into contracts and procurement processes • Consider climate-related risks and management in Environmental Impact Assessments / Environmental and Social Impact Assessments [59] • Incorporate climate-related risks into Risk Registers
Awareness-raising and organisational development	• Undertake training, staff development and capacity building programmes • Identify climate change 'champions' • Staff attend conferences and events on climate change
Working in partnership	• Work in partnership with stakeholders to understand climate change risks and develop co-ordinated adaptation measures: - Governments, regulators, external infrastructure providers, contractors, suppliers, customers, local communities • Partnership working helps to avoid conflicts between different organisations' adaptation strategies
Delivering adaptation actions	
Transfer: Spread/ share risks	• Diversify asset types and technologies for new Projects • Diversify locations of new Projects • Transfer risks through contracts with suppliers, contractors • Take out insurance to cover potential risks • Use other financial products that lay-off risk, such as Alternative Risk Transfer mechanisms (ART) including risk bonds, futures, derivatives, swaps and options

[59] For additional guidance on climate change and EIA, please refer to *Guidance for Integrating Climate Change and Biodiversity into Environmental Impact Assessment* due to be published by the European Commission in 2012.

Adaptation type	Description / examples
Treat: Avoid negative impacts	• Consider climate resilience as part of site selection process for new Projects – avoid locations where risks will be unmanageable • Implement climate-resilient design standards for new Projects • Implement changes to management regimes or operating rules for existing Assets • Implement engineering and technical solutions to build robustness against climate change for existing Assets as part of routine refurbishment or upgrades • Integrate climate-related risks into contingency and disaster plans for new Projects and existing Assets
Tolerate: Accept risks	• Accept risks where they cannot be managed or where cost-benefit analyses indicate that it is not worthwhile to make changes to existing Assets
Terminate: Bear loss	• Bear losses where they cannot be avoided – for instance, loss of coastal areas to sea level rise and/or increased rates of coastal erosion where risks are too expensive/difficult to rectify
Exploit opportunities	• Identify and develop new Projects that are favoured by future climate change conditions, e.g. increased solar potential due to increased sunshine hours in some locations

Annex XI: Further details on appraisal of adaptation options

1. Introduction

The annex provides further details on appraising adaptation options, to support application of Module 6.

Following the identification of the project's vulnerabilities and risks associated with climate change (Modules 1 to 4) and of technically and legally feasible adaptation options (Module 5), the next step in the preparation of the project for financing is to determine whether exposure to climate change risk is such that specific protection measures need be included in the project definition and if so, in which way.

The measure appraisal will differ from a 'conventional' one in that handling of uncertainty will be directly targeted, in place of the selection of 'optimal' maximum benefit solutions. Therefore a main feature of the measure appraisal will be how to handle this uncertainty and reduce risk exposure. This will obviously also depend on the risk taking willingness (risk attitude) of the decision maker.

2. Dimensions of measure appraisal

When initiating an option appraisal the objective of climate change risk exposure reduction should be expressed using quantifiable and project-relevant indicators.

The selection of an adaptation measure will be no different than in standard project analysis as detailed in, for example, the "Guide to Cost Benefit Analysis of Investment Projects" ('CBA Guide') of the European Commission[60]. The appraisal guidance described below takes this guide as its starting point and then expands on the features particularly relevant in a climate change adaptation context. This approach has the advantage that the CBA methodology and terminology in the CBA Guide is well known to decision makers. However, whereas the CBA Guide focuses almost entirely on option evaluation and prioritisation from a financial and economic feasibility perspective through the carrying out of a quantitative cost benefit analysis (CBA), the specifics of climate change adaptation may call for a broader approach to project evaluation.

First, in the evaluation of adaptation measures, it may well be the case that the CBA suggested in the Guide, involving valorisation of all costs and benefits, cannot be meaningfully performed. This is a feature well known in environmental projects. Often costs and benefits cannot even be meaningfully quantified.

Next, measures adopted in relation to climate change aim to reduce risk exposure, whereas the standard CBA of the Guide is concerned with the economic feasibility of the various options, with ranking done on the basis of net present value (NPV) of related cash flows only. Risk reduction is not the objective in the Guide and risk is addressed in terms of sensitivity testing of key variables only. As climate change is uncertain, the chosen option should also be robust to variations in the extent and nature of climate change. The degree of this robustness will depend on the risk tolerance level of the project proponent, and this is discussed further below.

Furthermore, and in particular for large scale projects where climate change risk exposure is an issue, it may be that regard has to be paid to *social feasibility,* more specifically how the population in different areas is affected by any adaptation measure selected. In a standard CBA recommended by the Commission, distributional aspects are not considered in the option evaluation and ranking. Economic feasibility and efficiency is the single evaluation objective.

[60] http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

In the costing guidelines reviewed for this assignment no integrated evaluation methodology has been developed. A common feature in the guidelines reviewed is the emphasis on three dimensions when assessing adaptation options, although addressed to a much differing extent[61]:

1. Economic feasibility (efficiency),
2. Uncertainty and risk,
3. Distributional impacts (social and political feasibility).

As noted, the economic feasibility dimension of the option evaluation is the single evaluation objective suggested in the CBA Guide. In this regard, some of the 'climate change specific' guidelines reviewed mention the problems of meaningfully quantifying and valuing option costs and benefits.

Addressing uncertainty and risk related to distributional aspects are already established extensions to the general CBA methodology. The specific features of climate change adaptation warrant their inclusion in option appraisal and prioritisation.

Due to the lack of existing, integrated appraisal guidance, the sections that follow combine relevant features of existing guidelines presenting approaches for addressing the three dimensions noted above, followed by suggestions for decision rules for option selection. Among the guidelines consulted are those of a generic nature such as the OECD guide on "Cost Benefit Analysis and the Environment - Recent Developments"[62] and the 'Green Book'[63] of the UK Treasury.

Before addressing these aspects, however, three additional features of general CBA methodology and their application for climate change adaptation will be presented. These relate to the definition of the project boundary, the establishment of the project baseline and the choice of discount rate and economic life for the calculation of net benefits of the options reviewed.

3. Basic assumptions for appraisal

3.1 Project boundary

As in any investment project, the definition of the project boundary is key for identifying the broader impacts of the project. When considering climate change, the impacts may be of a comparatively more indirect nature and more difficult to establish. Furthermore, the project boundary is also of relevance when discussing any distributional impacts of the adaptation measures.

A practical and useful means for impact identification are the 'impact matrices' suggested in the guidelines issued by the UK Climate Impacts Programme (UKCIP)[64]. These matrices present in overview the line of causality between a 'macro level' climate change event down to the project level, with impacts defined by indicators. Such matrices have been developed for coastal zones, water resources, agricultural, and buildings and infrastructure sectors[65].

[61] For an overview see e.g. UNFCCC: Potential costs and benefits of adaptation options: A review of existing literature. Technical paper, 11 May 2010. Available at http://unfccc.int/resource/docs/2009/tp/02r01.pdf
[62] Available at http://www.lne.be/themas/beleid/milieueconomie/downloadbare-bestanden/ME11_cost-benefit%20analysis%20and%20the%20environment%20oeso.pdf
[63] Available at http://www.hm-treasury.gov.uk/data_greenbook_index.htm
[64] "Costing the impacts of climate change in the UK - Overview of guidelines" chapter 3 and as detailed in "Costing the impacts of climate change in the UK – Implementation report", also chapter 3. Both reports available at http://www.ukcip.org.uk/costings/
[65] They are presented in an appendix to the UKCIP 'Overview' report.

3.2 Discount rate and project lifetime

In the standard CBA Guide of the Commission the discount rate for present value calculations is to be the same for the full reference period of the project, with the reference period for some projects being relatively short compared to the economic life of the assets. This approach mainly reflects the rate of time preference of the current generation. Furthermore, this constant rate does not capture the impact of uncertainty.

For environmental projects in general and climate change adaptation measures in particular the recommended approach, to the extent at all discussed in the literature, is to have the discount rate *decline* over time and with the NPV calculation covering the full economic life of the project. Often climate adaptation measures have a relatively long lifetime compared to the reference periods of the CBA Guide. Declining discount rates are recommended as a means first to include the impact on future generations in the assessment, thus introducing the concept of 'intra-generational equity'. Secondly, they are also a means to reflect uncertainty about the future state of the economy.

The UKCIP Guidelines referred to above recommend declining discount rates over time (UKCIP Implementation Report chapter 5). This recommendation is sourced from the UK Treasury 'Green Book' for project appraisal guidance, on which the UKCIP Guidelines are based. The UKCIP Guidelines give the recommended discount rates for the UK. As the choice of discount rate(s) is country specific, these rates and the structure of the decline is country specific, so they cannot necessarily be applied in other EU Member States. Further discussion of and arguments for time declining discount rates may be found in the OECD guide mentioned above on CBA and the Environment[66].

3.3 Project baseline

As in conventional investment project analysis, the '*incremental approach*' is to be applied, i.e. comparing the situation <u>with</u> the project (climate change adaptation option) and <u>without</u> the project, i.e. the project baseline.

In a standard CBA for an investment project, limited attention is paid to the definition of the project baseline. For 'green field' projects (without existing project assets), the baseline is effectively disregarded as all assets are new, and the 'without project' situation has no assets at all. For projects with existing assets, the baseline is usually just considered to be an extrapolation of the existing situation with the same level of costs and benefits ('do nothing' option).

In projects addressing climate change risk, the baseline is far from the existing situation. Indeed, the fundamental reason for considering adaptation measures is that the existing situation will change in the future due to changes in climate. Given the uncertainty about future climate change (which increases the further into the future one looks), more baselines (or scenarios) would need to be established in the cases of investments with relatively long economic lifetimes.

The climate change baselines for the project are to be defined on the basis of project-relevant outcome indicators (e.g. the change in power demand foreseen per unit of increasing temperature).

For costing purposes, impacts are then to be identified and valued for the costs/benefits of the project as well as the project baselines in order to arrive at the incremental net benefits (or avoided costs) of the proposed adaptation measure. This means that the impact matrices for establishing the project boundary need to be developed for the 'with climate adaptation' and the 'without climate adaptation' scenarios.

The establishment of the baseline will also be more complex than in a conventional project as it must take into account any climate change adaptation measures executed at the policy level that may impact on the project surroundings over its lifetime.

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[66] "Cost-Benefit Analysis and the Environment - Recent Developments", chapter 13.

4. Economic feasibility

Following the identification of impacts with the project and in the project baseline (with climate change) the impacts, whether costs or benefits, need to be quantified and valued. The quantification and valorisation over the project lifetime will be no different than in any standard option appraisal, and so it is only discussed briefly below for the sake of completeness. Instead, the focus of the guidance below is on emphasising specific climate change aspects.

4.1 Direct financial costs and benefits

The direct financial costs and benefits are the costs and benefits in money terms with direct impact on the project viz. investment costs, changes in operating costs and operating revenues when compared to any given baseline. As the costs and revenues have a market price, they are easily measurable.

4.2 Secondary economic impacts

The secondary economic impacts are the market impacts outside the project itself in terms of net value added to the economy. These impacts conventionally comprise indirect and induced impacts. Particularly important in assessing these impacts are two elements. First, the avoidance of double counting and secondly that impacts are to be established on a net basis within the region or country concerned. This means taking into account that e.g. any spending/income increases in one area may be offset by equally large spending reductions elsewhere.

4.3 Non-market impacts

Non-market impacts are those costs and benefits that do not have a market price and in all cases need valorisation. In some cases, the impacts cannot even be quantified. The impacts may be in the form of use value and non-use value (existence, option, and bequest values), if any, of the measure. The impacts to include are of course not only those related directly to reduction of climate change risk exposure but also other economic (non-financial) benefits and costs of the measure.

The user impacts may be valued either through the conduct of primary studies and surveys or through the application of the method of benefit-transfer. The primary studies would apply either the methodologies of 'revealed preference' or those of 'stated preference' as far as use value is concerned.

Often the conduct of such studies is beyond the financial means and time frame of investment projects. Instead the method of benefit-transfer is applied, whereby the results of any primary studies and cost/benefit estimations for a project in one sector or geographic area are used in a project in another sector or area. The challenge in the context of climate change adaptation is to identify relevant benefits and cost values for transfer. Information in this regard may be available from the relevant national authority such as the UK Treasury. At a general level, the Environmental Valuation Reference Inventory (EVRI) contains a database of studies with values for benefit-transfer[67].

The OECD Guide on CBA and the Environment referred to earlier presents an overview of valorisation of use and non-use benefits. A less extensive discussion, applying the economic valuation techniques to cultural infrastructure projects, has been prepared in the context of JASPERS[68].

In the special case where valorisation of the objective(s) of the measures as well as their effectiveness are the same and where valorisation of non-market impacts is not possible, a cost-effectiveness analysis (CEA) of feasible options may be carried out instead. In the general case, a qualitative judgment must replace and/or support the CBA or CEA.

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67 https://www.evri.ca/Global/HomeAnonymous.aspx

68 Staff working paper: "Best Practice on the Preparation of Projects in the Culture Sector (http://www.jaspers-europa-info.org/index.php/workpap/knowecoenrwaste.html)

4.4 Costing tool and case studies

To assist project proponents in option appraisal, UKCIP has developed an Excel based spreadsheet as well as a number of case studies illustrating their costing methodology[69]. The case studies are in the areas of health, heritage buildings, heritage gardens, highways asset management, property and insurance, and tourism.

4.5 Hedging effectiveness of measures

The options appraised as part of the economic feasibility assessment all have the common objective of protecting against climate change risk in the most efficient manner.

However, it may be that not all options are equally effective and expected to be able to offer the same level of protection or 'hedging'. Options in the control of the decision-maker through investments or operational improvements are more certain in their impacts than 'soft' options, whose effect, for instance, may depend on behavioural changes with consumers.

When measures cannot be expected to be equally effective, assessment of economic efficiency alone is insufficient. Obviously a soft option is economically efficient as little, if any, costs are involved but it may not have the intended impact. The degree of likely 'objective reaching' must therefore also be assessed and compared. This is also done in a standard CBA but is much less important given that the objective is economic efficiency on its own rather than risk protection.

In terms of climate change adaptation actions, the mirror image of hedging effectiveness is the size of the residual risk of the measure. The guidelines reviewed do not explicitly consider this efficiency dimension. The project developer should at least undertake a *qualitative* judgment of hedging effectiveness when comparing adaptation options and decide whether this open, residual risk should be hedged as well through (additional) insurance or other means.

In doing so, the project proponent should first recognise that no "perfect hedge" exists, and also note that the reduction of residual risk will come at additional cost.

5. Handling of uncertainty and risk

In the standard methodology of the Commission's CBA Guide, the appraisal of feasible options is carried out under an assumed high degree of certainty as to future 'states of nature' and outcomes. The risk assessment is confined to sensitivity testing, usually at standard ranges only and sometimes with calculation of switching values.

CBA in the context of climate change adds uncertainty to the economic feasibility assessment. The handling of this uncertainty and the associated risks is a key consideration in adaptation measure appraisal and eventually in measure selection.

Prior to assessing the risks, the decision-maker should determine the nature of the expected climate change risk that is relevant to the project. If the risk exposure of the project is deemed to be *gradually increasing one* over time, then in all cases it will be cost-efficient to adopt a phased approach to adaptation, with measures with relatively low levels of risk protection early on (and comparatively lower costs) followed by measures offering more protection later on[70].

If, on the other hand, the project risk exposure is judged to be in the form of a 'once and for all' increase in risk, then it is cost-efficient to achieve the desired level of risk protection early on.

[69] The spreadsheet costing tool and case studies applying the tool are found at http://www.ukcip.org.uk/costings/costing-spreadsheet/ and http://www.ukcip.org.uk/costings/case-studies/ .
[70] The efficiency of phasing-in of course also applies if the future climate was known with certainty.

For the risk assessment of the options, the sensitivity analysis of the standard CBA methodology will still be the starting point. However, rather than the conventional testing of the NPV impact by changing one or more exogenous key sensitivity variables/ assumptions within a pre-defined and probable range, the sensitivity testing should be primarily in the form of a (climate change) scenario analysis of the performance of the option or option mix. Within a scenario, and as in a conventional CBA, key variables should also be sensitivity tested to determine performance under uncertainty.

As suggested in the Commission's CBA Guide the range of testing should reflect the range of feasible scenarios for climate change over the given economic lifetime of the adaptation measure. For projects with longer lifetimes, the project proponent should at least define upper and lower bounds for the variation, as in the interval analysis of standard CBA methodology[71].

5.1 Probabilistic risk assessment

Based on the approximate likelihoods of climate impacts established in the earlier risk assessment (see Module 4, Table 12) indicative probability estimates may be assigned to the climate change scenarios of the baseline. This is particularly relevant for projects with long economic lifetimes where uncertainty is the greatest.

In the rare cases where fully probabilistic climate projections are available from reputable sources (e.g. national met offices), the model-generated probability distribution may instead be immediately applied in the risk assessment.

With probabilities assigned to the occurrence of the different scenarios, uncertainty may be incorporated in a CBA as well as in a CEA.

This is done by first calculating for each option the NPV of each future scenario with climate change as compared to the 'do nothing baseline' and next determining for each option the probability weighted average NPV, i.e. the expected NPV (ENPV) of this option in all scenarios[72]. For practical use, the NPV values across scenarios and options should be assembled in a 'state of nature' matrix.

The option with the highest ENPV would in standard CBA be considered the most attractive one. However, this assumes the decision maker to be indifferent or 'risk-neutral' as to the variation in NPV around the mean ENPV. If the decision maker is risk-averse, then the distribution of net benefits around the mean, i.e. the option robustness, will also be of importance in the option selection.

In a probabilistic risk assessment, this means taking into account in the option selection not only the probability weighted mean but also the standard deviation; the narrower the range of NPVs for an option, the less risky i.e. the more robust. As is well known in probability analysis, the standard deviation is a one-dimensional measure of risk not taking into account e.g. distributional skewness of outcomes.

5.2 Non-probabilistic risk assessment

In the majority of cases – i.e. where available climate change projections are such that they do not give sufficient confidence in assigning probabilities – other assessment methods may be applied for identifying the 'best' (most economically feasible) option in the sensitivity testing of various climate change scenarios (baselines).

[71] A variant of this is the so-called interval analysis, which takes the lower and upper values of the components of the climate change scenario assumptions, combining these values to define lower bound and upper bound values of the net benefits. The result may be a very wide bound for net benefits limiting the usefulness of this analysis form.

[72] Addressed e.g. in the UK Treasury Green Book and in the UKCIP costing guidelines ("Costing the impacts of climate change") as well as in the UKCIP report "Climate adaptation: Risk, uncertainty, and decision-making" http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Risk.pdf

The starting point is still the NPV of the adaptation measure(s) under each scenario and the resulting 'state of nature' matrix. A number of methods exist for taking uncertainty into account. Easily applicable methods in practical project preparation are shown in the box below.

Method	Assessment criterion
Baye's criterion	Assign equal probabilities to all scenarios and calculate ENPV
Maximax criterion	Preferred option is that with highest NPV overall
Maximin criterion	Preferred option has the highest minimum NPV of all options across scenarios.
Minimax criterion	Preferred option has lowest maximum NPV of all options across scenarios
Minimax - regret criterion	Calculate for each scenario the difference in NPV between that of the option and the highest NPV for all feasible options

Baye's criterion is a 'risk-unaware' measure, involving no more than calculating the simple average of the NPV of each measure in the various scenarios. The criterion reflects a neutral attitude towards risk taking.

The *maximax criterion* would be relevant for the 'risk-loving' project proponent: the level of the NPV in scenarios other than that of the highest NPV is disregarded.

In the *maximin criterion,* the selection of the lowest NPV for the various measures under consideration is a defensive or 'risk-averse' strategy. The 'best' option would be that with the highest minimum NPV regardless of scenario. By choosing the minima as selection criterion the approach seeks to avoid over-adaptation.

Using the *minimax criterion*, the 'best' option is the one with the lowest expected maximum benefit of the options considered. This is a risk-averse approach with bias towards 'do something' to adapt to climate change i.e. to avoid under-adaptation.

The *minimax - regret criterion* is also a risk-averse one: its aim is to minimise the loss that may be incurred across scenarios by choosing one option at the expense of other options, i.e. to minimise the disadvantage of the option selected, should it turn out in the future that another option would have performed better with the actual climate change experienced.

5.3 Quasi-option value

A key element of the uncertainty associated with climate change is its magnitude. As time progresses, this uncertainty will be reduced. For this reason it may be advantageous to delay the decision as to the extent of the adaptation measure to be used.

This is possible if the identified measure has an in-built flexibility in its design, such that extra climate change adaptation may be incorporated at a later stage when more information is available and thus uncertainty is reduced. This in turn reduces the risk – and cost – of the adaptation measure being unnecessary or oversized d. In projects where the climate change adaptation measure is a built-in part of the structure, e.g. a bridge or sewage pipelines, there may be no design flexibility.

The design flexibility in effect means an option exists for later upgrading. The value of the information secured through a decision delay is termed its quasi-option value in the field of environmental economics, (cf. e.g. the OECD Guide on CBA and the Environment, which also presents an illustrative example of the calculation of the expected (probability weighted) benefits with and without an environmental protection measure (chapter 10)).

A practical application in the field of climate change adaptation, showing how the changing probabilities over time come into play, is given in the supplementary Green Book guidance of the UK Treasury on “Accounting for the effects of climate change”[73].

6. Distributional impacts

For large scale investment projects in particular and for projects with a comparatively wide boundary in general, it may be that different parts of the population and/or economic agents within the boundary may be differently impacted, i.e. net benefits differ.

When this is the case, the project developer may wish to take into account distributional impacts in the appraisal and selection of adaptation options. This may be done in one of two ways:

1. Assign weights to the net benefits of each group in order to arrive at the aggregate benefits.
2. Present the distributional impacts as an explicit decision-making criterion to the project steering committee.

Either way, the consideration of distributional impacts will be subjective, either in defining the weights to assign, or in the importance attached to the impacts.

7. Decision rules

The selection of adaptation measures involves decision-making under uncertainty. The decision rule will then depend on the time frame of the project; the longer the lifetime the higher the uncertainty as to potential scenarios.

The rule would need to reflect the risk tolerance of the decision-maker, which may be risk taking, (‘risk lover’), risk neutral or risk averse.

A main distinction in setting up a decision rule is whether the objective of option selection is economic feasibility or whether other feasibility aspects, notably distributional aspects, also play a role. If the options under consideration are not equally effective as to climate change adaptation, this in all cases warrant separate consideration. This includes the so-called ‘win-win’ options, which provide benefits in other areas than climate change risk exposure reduction. Similarly it applies if not all costs and benefits of the economic feasibility calculation can be meaningfully valorised.

7.1 Single objective adaptation measure

With economic feasibility as the objective, the selected option should have a positive net present value. If not, the ‘do nothing’ option would be economically more attractive.

Measures with short time frames
Some adaptation measures have comparatively short economic lifetimes of, say, 5-10 years. In such cases, observed climatic trends based on recent climate data records, will provide a good indication of the climate conditions to be expected over the lifetime of the measure. In these cases, it would be sufficient and cost-efficient to perform a calculation of the estimated net benefits of the various options and to select the one with the highest positive NPV. If no measure has a positive NPV the option of ‘do nothing’ is preferable in economic feasibility terms. This corresponds to decision-making in a CBA with assumed certainty.

Risk tolerance level

[73] http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf

The <u>risk-loving</u> decision-maker should exclusively select the option with the highest NPV whether or not the risk assessment has been probabilistic. This would correspond to the maximax decision rule.

<u>Risk neutrality</u> in decision-making would, for the probabilistic assessment, be consistent with selecting the option with the highest weighted mean, the ENPV. In the non-probabilistic assessment, risk neutrality would be the simple mean of the Baye's criterion decision rule.

The fact that climate change uncertainty and risk is addressed at all by the decision-maker would point to the more likely level of risk tolerance being that of risk <u>aversion in relation to climate risks</u>.

The risk-averse decision-maker would aim at selecting options that perform robustly in terms of net benefits across climate change scenarios. If the level of net benefits is irrelevant, then the option with maximum robustness is to be selected.

Realistically, however, the risk-averse decision-maker would instead look at the return of the option, the expected net benefits relative to its robustness, i.e. would be willing to accept more risk if the return is higher.

In a probabilistic assessment this risk-return trade-off may be expressed by the coefficient of variance i.e. the standard deviation divided by the mean (ENPV). The option with the lowest coefficient is then the most attractive one. The standard deviations could also be used for calculating a risk premium for each option to include as a cost in the ENPV calculation, then conducting a Risk Benefit Analysis in place of a CBA.

Alternatively, and much less practically applicable, the decision-maker could make an expected value-risk analysis. This may be done by defining risk-return trade-off parameters in the form of the indifference curves of utility theory. The option with a risk-return trade-off highest on these curves is the preferred one. Such indifference curves could be constructed also for risk loving and risk neutral tolerance levels.

In a non-probabilistic risk assessment the decision-maker should first establish his/her own preferences for action against climate change risk, i.e. choose between the maximin, minimax, and minimax - regret and then select the option in conformity with the selected criterion. These preferences may also be incorporated in the probabilistic risk assessment by using them in place of the coefficient of variance or indifference curves; the choice is at the discretion of the decision-maker.

7.2 Multiple objectives

The decision rules with multiple objectives would include other targets than maximum economic efficiency. The conventional approach in this case is to carry out a multi-criteria analysis (MCA). An MCA should be performed in all cases where not all costs and benefits can be valorised, if a CEA for measures with the same benefit level cannot be carried out, and if the measures under consideration are not equally effective.

A formal MCA, or at a minimum a qualitative risk assessment, should also be performed in the cases of identified win-win options to ensure that the benefits over and above climate change risk exposure reduction are sufficient and not being dominated by ancillary benefits.

Furthermore, the use of an MCA will also allow separate weight to be attached to options with design flexibility, with reversibility features (regret options) and to differences in effectiveness and 'certainty of impact' of options, notably as to soft vs. hard options (see Section 4.5 above).

Various approaches exist for conducting an MCA but all involve subjective elements in the form of assigning scores and weights to the different criteria selected. However, in projects addressing climate change risk exposure the meaningful and 'objective' valorisation of benefits and costs will in many cases not be possible. An MCA will be preferable to an attempt to (subjectively) valorise all benefits as the subjectivity element is explicit.

8. Conclusions

The handling of risk and uncertainty in selecting climate change adaptation measures is necessarily of a subjective nature as no objective measure of risk exists and as the risk taking willingness and risk-return trade-off profile of decision-makers will vary. This makes it very difficult to develop a standard guideline for appraising and selecting climate resilience options in line with that of the European Commission's CBA Guide.

As to risk taking, the majority of decision-makers considering adaptation are likely to be risk averse with respect to climate risks and with the negative relationship between risk and return (net benefits) known from portfolio management principles. The implications for option appraisal and selection under uncertainty are then the following:

1. Establish decision criteria that seek robust solutions rather than economically optimal ones.
2. Seek to reduce risks by selecting a number of options – with different risk mitigating characteristics – rather than just one.
3. Include reversible options in the options for consideration, i.e. low cost options, including soft options, while paying attention to their likely effectiveness and certainty of impact relative to high cost investment options.
4. Ascertain whether high cost options may be flexible in design such that a time-phased approach to their implementation may be adopted, with the benefit of time reducing uncertainty and expected costs.
5. Assess any residual risks and determine if additional hedging is feasible and desirable (e.g. insurance cover).

A potential way forward for modifying the existing Commission CBA guidelines would be for the project proponent to demonstrate qualitative as well as quantitative approaches in their risk assessment, and to show that in the separate scenario sensitivity analysis, the climate change risk exposure of the project has been identified and, if need be, mitigated within the project proposal. Given the longer term nature of climate change project risks it appears advisable in the context of EU co-funding requests to extend the period of analysis from the comparatively short 'reference periods' to time frames that, for projects in all sectors, better reflect the expected economic life of the proposed investment.

References

Agrawala, S. and Fankhauser, S. (eds.) (2008). Economic aspects of adaptation to climate change. Costs, benefits and policy instruments, OECD, Paris.

ADB (2012). *Adaptation to Climate Change. The Case of a Combined Cycle Power Plant*. Summary Report. Asian Development Bank. Philippines.

Barnett, J. and O'Neill, S. (2010). Editorial. Maladaptation. *Global Environmental Change.* **20,** 211–213

ClimWatAdapt (Climate Adaptation – Modelling Water Scenarios and Sectoral Impacts), http://www.climwatadapt.eu/inventoryofmeasures (*last accessed 27/7/2012*)

Davis Langdon, an AECOM company, and Ecofys. (2011). Research to identify potential low regrets adaptation options to climate change in the residential buildings sector. Commissioned by the Adaptation Sub-Committee, available at http://www.theccc.org.uk/adaptation

DG REGIO. (2008). Guide to Cost Benefit Analysis of Investment Projects.

EC. (2010). Commission Staff Working Paper *Risk Assessment and Mapping Guidelines for Disaster Management* . SEC (2010) 1626 final. European Commission, Brussels.

HM Treasury (2003). Appraisal and evaluation in Central Government. The Green Book, Treasury Guidance, London.

IFC. (2010). Climate Risk and Financial Institutions: Challenges and Opportunities.

IPCC. (2001). Climate Change 2001: Impacts, Adaptation and Vulnerability, *Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J. J.; Canziani, O. F.; Leary, N. A.; Dokken, D. J.; and White, K. S., (eds.)]. Cambridge University Press, Cambridge, United Kingdom.

IPCC. (2007a). Climate Change 2007: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 976 pp.

IPCC. (2007b). Climate Change 2007: The Physical Science Basis. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Metroeconomica. (2004).Costing the impacts of climate change in the UK. Implementation report. UKCIP.

OECD. (2010). Innovative financing mechanisms for the water sector. OECD Working Party on Global and Structural Policies. ENV/EPOC/GSP(2009)11/FINAL.

Pearce, D.W., Atkinson, G., Mourato, S. (2006). Cost-benefit analysis and environment: recent developments, OECD, Paris.

Raper, S. C. B., Wigley, T. M. L. and Warrick, R. A. (1996). Global sea level rise: past and future. In: Milliman, J. D. & Haq, B. U. (eds.) Sea Level Rise and Coastal Subsidence: Causes, Consequences and Strategies. Dordrecht, the Netherlands: J. Kluwer Academic Publishers.

Stott, P., A., Stone, D., A., and Allen, M., R. (2004). Human contribution to the European heat wave of 2003. *Nature.* **432**, 610-614.

UK Adaptation Sub-Committee. (2011). Adapting to Climate Change in the UK: Measuring progress. Progress report.

UN/ISDR (Inter-Agency Secretariat of the International Strategy for Disaster Reduction). (2004). Living with Risk – A global review of disaster reduction initiatives.

UNDP. (2007). *Human Development Report 2007/2008. Fighting climate change: Human solidarity in a divided world*. Published 2007. New York. USA

Wilby and Dessai. (2010). *Robust adaptation to climate change.* Royal Meteorological Society. UK

Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making.* UKCIP Technical Report, UKCIP, Oxford.

World Bank. (2009). Albania. Climate Vulnerability Assessments. An Assessment of Climate Change Vulnerability, Risk and Adaptation in Albania's Power Sector. Report No. 53331-ALB.